THE WORLD'S DAIRY CONGRESS

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The World's Dairy Congress is to be a conference of international representatives of the dairy industry, its related sciences and public health and social welfare agencies. Its purpose is to bring together the forward-looking leaders who are shaping the trend of science and industry; to exchange the newer knowledge of the science and practices of dairying and allied activities; to study the economic forces which influence domestic and international commerce in dairy animals, products and equipment; to discuss methods of disease prevention and of regulating and controlling the sanitation and standards of dairy products; to consider the influence of a wise use of milk and its products on national health and the vital importance of the part which they play in human physical and mental development.

Acting under the authorization of a law of March 3, 1921, the President of the United States has invited all Governments to send representatives to the sessions and, in addition, the World's Dairy Congress Association has invited institutions, firms and associations of this and other lands to send delegates and has asked the Governors of all the States of the Union to attend the sessions and appoint commissions to represent their dairy and allied interests. The Congress will hold its opening sessions at Washington, D. C., on October 2 and 3, adjourn to Philadelphia, Pa., for October 4 and continue at Syracuse, N. Y., from October 5 to 10.

The dairy industry is passing through a transitional period. The war and the after-war conditions have forced it into a world readjustment. The shift in international dairy trade and the struggle to regain pre-war business have made the problems of the industry world problems. While damming up the normal flow of international scientific information, the war resulted

in many new discoveries, particularly in the principles of human nutrition. The World's Dairy Congress offers an opportunity to bring these facts to the attention of all nations through discussion by scientists, welfare workers and business men.

Progress in all countries and in all industries is stimulated by the exchange of experience and information. Attendants will derive much benefit from personal contact with the leaders from other nations, whose problems are similar to their own, as well as by attending the formal sessions. Each country has something to contribute, each has something to gain.

The men in all countries, who have made outstanding contributions to the science or business methods of dairying or to public health work through the use of dairy products, have been invited to participate in the program of the World's Dairy Congress. Acceptances indicate that the most pressing problems in research, regulation, economics and use of dairy products, now confronting the industry and society, will be thoroughly considered in this program and that the most important achievements of the last ten years will be presented for the service of the whole world.

The program for the World's Dairy Congress will include about two hundred papers well distributed among the various branches of the industry. Since it will be impossible to present all of these papers to the entire Congress in the time available, it will be necessary to hold at least four simultaneous sessions daily. The two days in Washington will be devoted to general sessions at which will be discussed questions of general interest, particularly international trade and the general world development of the industry and its relation to human welfare.

Abstracts of all papers submitted early enough will be available to delegates in English, French, German or Spanish at the time of registration. Discussions may be in any one of the four languages at the Congress sessions and interpreters will translate what is said. The program has been arranged to interest the following groups:

I. Research and Education—teachers, investigators, officials, engineers and other technical men, interested in the solution of dairy problems.

II. Industry and Economics—men engaged in breeding dairy cattle and in producing, manufacturing, exporting, importing, storing and distributing dairy products and equipment.

III. Regulation and Control—national, state, municipal and private officials, concerned with standards, adulteration, sanitation and animal disease control.

IV. National Health—public health and nutrition workers, philanthropists, social welfare workers, and students of the influence of diet on the health and vigor of all nations.

At Washington, D. C., foreign delegates will be formally received by Government officials and greeted by American dairy scientists and leaders. The opening sessions will include discussions of some of the most interesting papers of the program, especially those dealing with the broadest international topics—scientific, economic and humanitarian—with addresses by men of world-wide reputation. A reception, a dinner and visits to research laboratories, public buildings and historic places will be a few of the activities in this city.

At Philadelphia, Pa., a full day will be devoted to a complete display by the National Dairy Council of its methods and results in promoting health by the proper use of milk and its products. An opportunity will be given to visit manufacturing and milk-distributing plants and places of historic interest. In the evening there will be a banquet with speakers of international reputation and an original program by the National Dairy Council.

At Syracuse, papers relative to particular subjects will be presented at group meetings each forenoon. The papers will be grouped, as far as possible, to bring together those on related subjects. Thus, there will be one session devoted to breeding, one to feeding problems, one or more to the chemistry and bacteriology of cheese, at least two to coöperative marketing problems, one or more to transportation and other problems of the city milk dealer, and many other similar groups.

The program has been planned to present the status of the dairy industry of the world as it exists today. The great diversity of subjects, which must be included to cover all the varied

ramifications produced by the rapid development of the last few decades, will require two radical departures from the programs of preceding congresses.

An entirely new section will be devoted to the part played by milk and its products in promoting the health of the people. Two phases of this subject will be presented. One of these will consist of the recent advances in the science of nutrition, particularly where that science deals with the peculiar characteristics which make milk important in promoting growth and vigor. The other phase will consist of ways and means of conveying this information to the public.

The second departure from preceding programs will consist in the attention to be devoted to national and international economic and trade problems. One session will be devoted to a discussion by prominent economists of questions of international trade in dairy products and the relation of business conditions in general to the dairy industry. The program will include numerous papers on the technical questions involved in the manufacture of dairy products. It will also give particular attention to questions interesting those who produce, buy, sell and manufacture dairy products and equipment used in the dairy industry and to economic questions connected with the movement of dairy products in international trade and involved in the relation of world conditions to prices.

Because of the very general interest, considerable time will be devoted to papers on coöperative organizations, particularly organizations formed by producers to sell products. These papers will deal largely with the principles which are essential to success and the defects which have been the cause of friction. Delegates from countries in which coöperative marketing has been highly developed will take part in this section of the program.

The problems of the city milk dealers will be discussed in a series of papers by authorities from different parts of the world on transportation, distribution and other pertinent questions, such as the development of bulk transportation of dairy products by tank car and truck. The adjustment of prices and the

factors which determine cost of production will be considered. The manufacturers of dairy equipment will be interested in a group of papers on the selection of materials for dairy machinery and utensils and the standardization of equipment and containers.

The part of the program devoted to Regulation and Control will include discussions of the administration of laws, safeguarding the producer and the consumer of milk and milk products from fraud and infection by disease bacteria. Measures used by the industry itself for the improvement of the milk supply will be considered.

In general, papers will deal with the broader aspects of dairy problems; but technical papers of special interest to the investigator and teacher will be added. A general outline of the system of agricultural education and investigation in the United States will be presented and detailed attention will be given to methods of dairy education by authoritative speakers from the leading dairy countries.

In the section on Research and Education, will be included a collection of papers on the physiology of milk secretion and the chemistry of milk, summarizing the world's knowledge of these subjects. A number of the most active of the investigators of these problems will take part. Some problems of the breeder will be presented by prominent investigators. The diseases of dairy cattle will be considered in a symposium on the more serious ones. A number of prominent bacteriologists will discuss the group of bacteria of importance in dairying.

A COMPARISON OF EARLY, MEDIUM AND LATE MATURING VARIETIES OF SILAGE CORN FOR MILK PRODUCTION

REPORT OF SECOND FEEDING TRIAL

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The results of the first trial having been reported (1), interest in the work seems to warrant the publication of the data obtained in the second year, together with averages of both. A third trial is being run on the same plan. As stated in the first paper, the problem of the northern dairyman is not one of date of harvesting, or proper stage of maturity for a given variety, but the selection of a type or variety which will make the most milk per acre. It seems to be accepted that steers will not make the most profitable gains on immature silage, but for milk production this is an open question.

Chemical analysis easily establishes that 100 pounds of mature corn silage contains more total nutrients than the same weight of silage made from immature corn. Also several careful investigations, notably that of the Indiana Experiment Station (2), have given us data on the rate of increase in dry matter and the various constituents up to maturity for a given variety or type; so that so far as date of harvest for maximum yield of dry matter is concerned, the question is settled.

However, nine years of field tests at this station have proven that large growing, late maturing varieties will produce more dry matter per acre, even when harvested very immature, than varieties that mature in this region. The question then arises: "Is the greater theoretical feeding value *per ton* of the early

types, sufficient to offset the greater yield of dry matter *per acre* of the late types?" It is this question that these feeding trials are designed to answer.

EXPERIMENTAL PROCEDURE

The second feeding trial was carried on in the same manner as the first, there being four cows in each group, with the exception of the medium, which includes only three. All animals were fed the same amounts of silage (50 pounds, except one animal in each of the Early and Late Groups) the grain being varied to maintain constant weight. Six pounds of hay per cow per day were fed this year instead of four as in the first trial. This hay was purchased on the market and was a mixed grade, largely timothy. All feeds were sampled and analyzed in the same manner as described in the previous paper. No unusual conditions arose during the actual experimental period of one hundred days. The preliminary feeding started on January 11, with regular herd silage. Experimental silage was started January 31, and the one hundred day period was begun February 20.

Notes on animals and feeding

As far as possible the same cows were used as in the previous trial, except that they were changed to other groups. Thus Fusion, Colony and V. J. Storrs were changed from late to early. Likewise Pansy and Fruition here in the late group were previously in the early, while Storrs Robin 2d came from the medium group of last year to the late of this. Simple alone remained in her original group—medium. Grades 257, 258, 259, and 260 were purchased as springers a short time prior to this trial for this specific purpose.

Fusion was in quite good condition when she calved and because of her milking tendency it was necessary to allow a considerable loss in weight (56 pounds). On the whole, the individuals balanced satisfactorily. The weights were controlled as described in the previous report.

All cows except V. J. Storrs and Storrs Robin 2d were fed 50 pounds of silage daily. These two were fed 40 pounds daily. Fruition, in the late group, was off feed for a few days early in the experiment. All cows ate within less than a pound per day of their silage allowance for the one hundred days. The hay was eaten clean from one feeding at noon. By feeding grain to keep the weight constant, the appetite of all cows remained remarkably good, no trouble resulting after the experiment was under way. The grain ration as before consisted of three parts yellow corn meal (no. 2), three parts wheat bran, and two parts cottonseed meal (36 per cent).

The medium group in both the first and present trials was not balanced as closely in weight and milk production with the other two groups as would be desirable. Emphasis was placed on the two extremes and the remaining animals were placed in the medium silage. In the third trial the medium (Leaming) silage has an equal opportunity.

THE TYPES OF SILAGE CORN

The same three varieties were used as in the first trial, these being chosen as best representing the three types we desired to compare. They were all planted on the same day, May 26, 1921, in adjacent plots and harvested on three consecutive days before frost, September 16 to 20. They were grown in a twenty-two acre field regularly devoted to raising crops for the dairy herd. To answer questions regarding these varieties the following data is given:

Early type. A strain of "Pride of the North," originally secured from Cornell Station and grown at Storrs for twelve years. Ripens at Storrs in one hundred and thirty days.

Medium type. A strain of "Leaming," seed for which is secured each year from the same grower in Clark County, Ohio. Ripens in one hundred and forty days at Storrs. Our season is seldom long enough for it to ripen.

Late type. "Eureka," a very large growing white corn, seed for which is secured each year from the same source in Virginia. Has seldom reached dent stage at Storrs.

Table 1 gives the data on the corn as grown in 1921 for this trial, and table 2 the average results obtained for these varieties on the test plots over a period of years.

TABLE 1

Data on silage as harvested—second trial 1922 (corn grown in 1921)

All planted and harvested at the same time

TYPE	STAGE OF MATURITY	PER CENT OF TOTAL GREEN WEIGHT							ACTUAL YIELDS PER ACRE AS GROWN FOR FEEDING TRIAL
		Water	Dry matter	Ash	Crude protein	Crude fiber	N.F.E.	Fat	
									tons
Early	Ripe, husks drying	66.19	33.81	0.95	2.60	5.56	23.41	1.00	12.4
Medium	Soft dough	73.77	26.23	1.07	1.71	5.93	16.89	0.63	16.4
Late	Early milk	77.29	22.71	1.00	1.26	6.66	13.50	0.29	21.2

All the corn grown in 1921 for this trial (table 1) shows less water than the average composition (table 2). The season was longer and the silos were not filled as early as usual. Note that they all show greater maturity.

TABLE 2

Averages of several tests on these varieties

All planted and harvested at the same time

TYPE	STAGE OF MATURITY	WATER	YIELD PER ACRE	
			Green weights	Dry matter
		per cent	pounds	pounds
Early	Hard dough	73.80	24,774 (12.4T.)	6491
Medium	Soft dough	78.09	32,947 (16.5T.)	7218
Late	Kernels forming	80.16	40,648 (20.3T.)	8064

TABLE 3

Analysis of feeds as fed—second trial, 1922

	WATER	DRY MATTER	ASH	CRUDE PROTEIN	CRUDE FIBER	N.F.E.	FAT
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Timothy hay	3.02	96.98	4.75	6.81	28.84	53.81	2.77
Grain	8.60	91.40	4.60	17.44	8.09	56.36	4.97
Early silage	68.36	31.63	1.26	2.50	6.59	20.31	0.96
Medium silage	75.09	24.90	1.23	1.75	5.91	15.30	0.69
Late silage	79.76	20.23	1.14	1.41	6.35	10.61	0.49

Grain is not so high in water this year. Corn was kiln-dried on day of grinding and mixing.

The per cent of water is greater in the silage than in the green corn as cut in, due to the fermentation, one product of which is water.

TABLE 4

Data concerning experimental cows—second trial, 1922

One hundred days—February 20 to May 30—experimental.
Forty-one days—January 11 to February 20—preliminary.

	BREED	AGE	CALVED	CONCEIVED	INITIAL WEIGHT	FINAL WEIGHT	AVERAGE WEIGHT	EXTREME VARIATION FROM INITIAL WEIGHT	DATE OF EXTREME VARIATIONS	GAIN OR LOSS IN WEIGHT
Early group										
		years								
Fusion	P. B. Hol.	5	12/22/21	5/18/22	1405	1349	1378	1344	5/25	−56
258	Gr. Hol.	10	11/26/21	3/19/22	1127	1120	1135	1149	4/9	− 7
Colony	Gr. Hol.	5	12/17/21	3/ 3/22	1117	1153	1144	1159	4/17	+36
V. J. Storrs	P. B. Jer.	7	11/ 6/21		903	896	906	913	4/2	− 7
Medium group										
257	Gr. Hol.	9	11/20/21	3/31/22	1001	976	990	974	5/29	−25
259	Gr. Hol.	7	12/ 4/21	3/12/22	1058	1087	1077	1087	5/30	+29
Simple	P. B. Guer.	10	11/ 2/21	3/ 4/22	1024	986	1010	981	5/26	−38
Late group										
Pansy	P. B. Hol.	8	1/ 5/22	5/20/22	1090	1131	1113	1131	5/30	+41
Fruition	P. B. Hol.	5	1/17/22	3/29/22	1192	1171	1169	1143	3/31	−21
260	Gr. Hol.	6	12/31/21	2/27/22	1095	1097	1096	1080	5/6	+ 2
S. Robin 2d	P. B. Jer.	9	11/19/21	1/27/22	915	901	908	890	5/22	−14

TABLE 5

Average daily consumption of feed per cow—second trial, 1922

GROUP	GRAIN			SILAGE			HAY			TOTAL DRY MATTER
	Amount	Protein	Dry matter	Amount	Protein	Dry matter	Amount	Protein	Dry matter	
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Early	7.313	1.271	6.684	47.468	1.186	15.015	5.997	0.408	5.816	27.515
Medium	7.161	1.245	6.546	49.885	0.875	12.422	5.994	0.408	5.813	24.781
Late	8.622	1.499	7.880	46.696	0.663	9.449	6.000	0.408	5.819	23.148

TABLE 6

Average daily production per cow—second trial, 1922

GROUP	MILK	FAT	TOTAL SOLIDS	MILK COMPUTED TO 12 PER CENT SOLIDS	TOTAL SOLIDS IN MILK
	pounds	*pounds*	*pounds*	*pounds*	*per cent*
Early	25.546	0.8929	3.0406	25.354	11.91
Medium	20.728	0.8100	2.6075	21.730	12.58
Late	22.327	0.8301	2.6942	22.457	12.07

RESULTS FOR BOTH TRIALS

Both trials were run on the same plan—that is, silage was fed in the same quantity for each group. In order to average the results of both, the data for the first trial has been arranged in the same manner as in Table 7.

Tables 7 and 8 give a chance for comparison of the two years results. They are consistent. The less dry matter required for 100 pounds of milk in the first trial is partly due to the larger yields of milk the first year. The yields for one hundred days for the two years per cow follow: Early—2828.2 pounds in 1921, and 2554.6 pounds in 1922; medium—2293.8 pounds in 1921, and 2072.8 pounds in 1922; late—2920.6 pounds in 1921, and 2232.7 pounds in 1922. The difference in yields was due mostly to the particular character of the cows, the grades which were purchased not being in so good condition at calving time.

TABLE 7

Pounds feed and dry matter consumed—second trial, 1922

Per 100 pounds of milk

GROUP	SEPARATE FEEDS—MILK AS PRODUCED						TOTAL DRY MATTER PER 100 POUNDS MILK		
	Silage		Grain		Hay		As produced	Milk of 12 per cent solids content (1)	With adjustments for weight and 12 per cent milk (2)
	Total	Dry matter	Total	Dry matter	Total	Dry matter			
Early	185.81	66.20	28.941	26.452	23.475	22.766	115.42	116.29	116.29
Medium	240.66	59.92	34.280	31.330	28.920	28.050	119.30	113.80	116.71
Late	209.15	43.31	39.597	36.190	26.870	26.060	104.56	103.95	105.19

(1) The milk varied slightly in total solids, with the three groups. The total solids produced is used and the dry matter in feed is computed in this column to the amount that would have been required for 100 pounds of 12 per cent milk in each group.

(2) There were differences among the average weights by groups, the Early weighing most, the Late next and the Medium least. Coefficients of digestibility from Henry and Morrison (table 2) were applied to the analyses of feeds as fed (table 3, this manuscript), maintenance requirements were calculated from the Henry-Morrison modified standards and expressed in terms of dry matter. These adjustments, together with those for milk quality, were applied in computing the last column. Thus the three groups are placed on as uniform a basis as possible.

TABLE 8

Pounds of feed and dry matter consumed—first trial, 1921

Per 100 pounds of milk

GROUP	SEPARATE FEEDS—MILK AS PRODUCED						TOTAL DRY MATTER PER 100 POUNDS OF MILK		
	Silage		Grain		Hay		As produced	Milk of 12 per cent solids content	With adjustments for weight and 12 per cent milk
	Total	Dry matter	Total	Dry matter	Total	Dry matter			
Early	159.00	40.93	35.405	31.27	14.14	13.54	85.74	81.33	81.33
Medium	199.01	50.09	35.816	31.64	17.40	16.66	98.39	85.74	90.06
Late	155.92	30.30	39.780	35.14	13.70	13.12	78.56	76.52	76.79

The yields per pound of grain fed are illustrated as follows: early—2.84 pounds in 1921, and 3.49 pounds in 1922; medium—2.76 pounds in 1921, and 2.89 pounds in 1922; late—2.54 pounds in 1921, and 2.59 pounds in 1922. This milk increase per unit of grain is greatest in the early group. It should be recalled that the silage in 1922 was more mature for each variety and more especially the early, which contained 5.9 pounds less water per 100 pounds silage in 1922. Also the additional amount of hay (200 pounds per cow) must have effected a saving in grain. Had the yields of milk for the two years been the same, the value of the additional hay and slightly richer silage would doubtless have been more apparent in the medium and late

TABLE 9

First and second trials combined to show relative efficiency of the silage

GROUP	TOTAL POUNDS DRY MATTER PER 100 POUNDS MILK OF 12 PER CENT SOLIDS AT UNIFORM LIVE WEIGHT				RELATIVE EFFICIENCY OF SILAGE	
	First year	Second year	Average*	From silage*	Equal to 100 pounds early	Acres to equal early
Early	81.33	116.29	101.31	55.37	100.0	1.00
Medium	90.06	116.71	103.39	55.01	102.7	0.77
Late	76.79	105.19	93.02	37.75	134.7	0.82

* Weighted average.

groups. In 1922, with the lower production, a greater percentage of the total feed consumed was naturally used in maintenance.

When the two trials are arranged, and an attempt made to rate the acre values of the three types, the data shown in table 9 is obtained.

During both years the dry matter required to produce 100 pounds of milk was least with the immature (late) silage, and greatest with the medium. This difference is undoubtedly due to the difference in the proportion of grain fed, the late group consuming considerably more grain and the medium group the least amount (least with the medium, because the production was least). The pounds of dry matter from silage for each

100 pounds of milk for the early, medium and late was 55.37, 55.01, and 37.75 respectively.

On this basis, 100 pounds of early silage was equivalent to 102.7 pounds medium silage, and 134.7 pounds late silage. Calculating to the acre yield (table 2) 0.77 of an acre of medium and 0.82 of an acre of late were equivalent to an acre of the early corn

Table 10 is arranged to show the milk production value per acre from the two years' trials.

TABLE 10

Showing milk production value of silage

GROUP	PER 100 POUNDS 12 PER CENT MILK—WEIGHTED			MILK PER POUND DIGESTIBLE DRY MATTER	MILK FROM DIGESTIBLE DRY MATTER IN SILAGE	SILAGE TO FURNISH 1 POUND DIGESTIBLE DRY MATTER WEIGHTED	SILAGE FOR 1 POUND MILK	MILK PER ACRE
	Dry matter	Digestible dry matter	Digestible dry matter from silage					
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Early	101.31	67.81	36.54	1.47	53.71	5.2	3.5	7078
Medium	103.39	68.65	35.75	1.46	52.20	6.1	4.2	7663
Late	93.02	62.27	24.16	1.61	35.39*	7.9*	5.4	7527

* Average of milk per pound dry matter as determined with Early and Medium is used in this calculation. The greater amount of grain consumed by the Late Group furnished these cows with a ration of greater digestibility which account for the better showing of this Group in column 3 (Table 10). In the first trial the amount of grain required daily by the Early, Medium and Late Groups was 9.97, 8,31 and 11.60 pounds respectively; and in the second trial it is 7.3, 7.2, and 8.6 pounds respectively.

The calculations in this table are on the basis of the dry matter consumed and coefficients of digestibility from appendix table II, Henry and Morrison's Feeds and Feeding, 18th edition. The coefficient applied to the grain mixture, 77 per cent, is a weighted average. For the hay, 55 per cent was used, for the early silage 66 per cent, for the medium silage 65 per cent, and for the late silage 64 per cent.

A pound of digestible dry matter in the silage was assumed to have the same value as one pound of digestible matter in the hay and grain. While this is not strictly true, as is well known and as is shown in column 3 (table 10), it furnishes a satisfactory basis for comparison when the milk per pound of dry matter for the early and medium silage in column 5 is applied, which then only assumes that the digestible dry matter of the different silages is of equal value; and the amounts of silage actually consumed are nearly identical.

Column 6 (table 10) gives the amount (pounds) of silage required to produce one pound of digestible dry matter and column 7 gives the pounds of silage required to produce one pound of 12 per cent milk (including maintenance). On this basis it was found that an acre of early (12.4 tons) will produce 7078 pounds milk, the medium (16.5 tons) 7663 pounds, and the late (20.3 tons) 7527 pounds. This comparison indicates that such an early corn as Pride of the North will not feed enough better to offset its low comparative acre yield; but Leaming, which forms good ears and makes a good yield has a greater production value than either of the others.

It is realized that these calculations cannot be considered final. They are offered as the present attempt at solving the problem. A third year's feeding trial is now being run. Further work needs to be done to compare the dry matter values of the different silages. This is an experiment which it is planned to carry out in 1924. There is also a possibility that there are greater losses in dry matter in the silo from some types than from others which is a point we hope to determine. Then there is the question of cost of growing and ensiling the different types.

SUMMARY

The second year results support those of the first year. All of the silages were a little more mature the second year, containing more dry matter, and this was markedly true of the early silage.

The grain required per 100 pounds of milk when the amounts of hay and silage were the same for all groups was 28.94, 34.28 and 39.60 pounds respectively for early, medium and late silage.

The area of corn required by medium and late to equal an acre of early in feeding value (two years combined) is 0.77 and 0.82 respectively.

The silage required for one pound of milk of 12 per cent solids is 3.5 pounds of early, 4.2 pounds of medium and 5.4 pounds of late.

The pounds of milk produced per acre of silage is 7078 from early (12.4 tons), 7663 from medium (16.5 tons) and 7527 from late (20.3 tons). These yields were obtained from cows during their first five lactation months.

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THE DETERMINATION OF FAT IN BUTTERMILK

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INTRODUCTION

An accurate method for the determination of fat in buttermilk is necessary in order to control the exhaustiveness of the churning process. Some of the larger creameries are so equipped that it is possible to determine churn losses by means of a chemical analysis of the buttermilk. The Roese-Gottlieb and Mojonnier tests are the ones commonly used for this purpose. In most cases, however, the testing equipment in the smaller plants consists only of the Babcock test outfit, which affords a cheap and rapid method for the determination of fat in milk products.

Certain procedures have been developed and certain types of test bottles have been produced for testing whole milk and cream, but for buttermilk there is no standard method of testing, nor is there an adequate test bottle. Buttermilk is tested in the ordinary 18-gram skim milk bottle, which is graduated from 0.0 to 0.25 of 1 per cent (a few bottles graduated from 0.0 to 0.50 of 1 per cent are being put on the market), whereas the amount of fat in buttermilk will, in some cases, exceed 1 per cent. It is only in extremely rare instances that the calibrated portion of the neck of the skim milk bottle is of sufficient size to measure the fat contained in an 18-gram sample of buttermilk.

It was for the purpose of determining the limitations of the Babcock method for testing buttermilk, and if possible of devising a satisfactory modification, that this investigation was carried on.

PLAN OF WORK

The experiment was so conducted as to obtain information on the following points:

A. The conditions limiting the use of the Babcock test for buttermilk.

1. The amount of sulphuric acid used.
2. The length of the whirling period.
3. The speed of centrifuging.

B. A comparison of the Babcock, Normal Butyl Alcohol, (1) and Roese-Gottlieb methods for determining the amount of fat in buttermilk.

METHOD OF PROCEDURE

The buttermilk used in the experimental work was obtained from the churning of neutralized cream in a Dual churn and worker.[1]

All the Babcock and Normal Butyl Alcohol tests were conducted in an electric centrifuge with speed adjustment ranging from 850 to 1700 revolutions per minute, and having a 22-inch disc.

The acid was measured directly into the test bottle from a burette, as it was found that accurate measurements could not be obtained by the use of an acid measure or graduated cylinder. The sulphuric acid used had a specific gravity of 1.83.

Skim milk bottles graduated from 0.0 to 0.50 of 1 per cent were used for the normal butyl alcohol tests, and bottles graduated to 0.25 of 1 per cent were used for the Babcock tests.

ROESE-GOTTLIEB DETERMINATIONS

In general, the procedure as given by the Association of Official Agricultural Chemists (2) was followed in the Roese-Gottlieb determinations. Three extractions with ether were made in each case. It was found necessary to use more ammonia than is needed in testing other milk products, and it was often

[1] With the exception of sample 12, table 4, which was hand churned buttermilk.

necessary to add ammonia in the second and third extractions in order to break the emulsion which formed upon the addition of ether. The total amount of ammonia used for a 5-gram sample varied from 2 to 6 cc.

THE NORMAL BUTYL ALCOHOL TEST

The Normal Butyl Alcohol procedure was that reported by Prof. W. J. Mitchell (1) and was as follows:

Chemicals: Commercial sulphuric acid. Normal butyl alcohol

1. Add the chemicals and buttermilk to the test bottle in the following amounts and in the order indicated:
   (a) 2 cc. of n-butyl alcohol
   (b) 9 cc. of buttermilk
   (c) 7–9 cc. of commercial sulphuric acid.

Vary amount of acid to suit its strength. The right amount is being used when the fat column is golden yellow to light amber in color.

2. Mix contents of bottle thoroughly
3. Centrifuge for 6 minutes
4. Add hot water (soft or distilled) to fill bottle to bottom of neck, and whirl 2 minutes.
5. Add balance of water to float fat into neck and again whirl 2 minutes.
6. Read at a temperature of 135°–140°F. Double the reading to obtain percent of fat.

THE BABCOCK TEST

The unsatisfactory results of several preliminary tests following the more common method of testing buttermilk, which makes use of an 18-gram sample and about 20 cc. of commercial sulphuric acid, led to a study of the following variations of the Babcock test for buttermilk.

1. A 10-gram sample (as measured by a 10-gram Mojonnier pipette) was used.
2. Comparative tests were made, using 11 and 13.5 cc. of sulphuric acid.

3. The following three whirling periods were compared:

a. 20 minutes—20 minutes—10 minutes
b. 10 minutes—10 minutes—5 minutes
c. 5 minutes—3 minutes—3 minutes

4. The effect of the speed of centrifuging was determined by a comparison of the results obtained at the following variations:

a. 850 R. P. M.
b. 1150 R. P. M.
c. 1700 R. P. M.

EXPERIMENTAL DATA

A. Conditions limiting the use of the Babcock test for buttermilk

1. The amount of acid used. As the maximum amount of acid that could be used without danger of charring the fat globules had been found to be 13.5 to 14 cc. (sp. gr. 1.83), 13.5 cc. was selected as the maximum amount of acid to be used in the investigation. Eleven cubic centimeters was arbitrarily selected as the minimum quantity that would be used in determining the importance of the amount of acid. The influence of the amount of acid is shown by table 1.

Table 1 gives a comparison of the results obtained from running seven different samples at a 10–10–5 whirling period and at 1150 R.P.M., using the two different amounts of acid. It will be seen that a much lower reading was obtained from the use of 11 cc. of acid than when 13.5 cc. were used. The average percentage of fat obtained with 13.5 cc. of acid was more than twice that obtained with 11 cc. of acid. These data clearly show the importance of using the maximum amount of acid.

2. The length of the whirling period. The following tables present a comparison of the results obtained from three different whirling periods at a speed of 850 R.P.M. using 13.5 cc. of acid, and from two different whirling periods at a speed of 1150 R.P.M. using both 11 and 13.5 cc. of acid.

These data show that the length of the period of centrifuging is of minor importance. Under the conditions indicated in part I of the table the longer whirling periods resulted in slightly

higher average fat percentages. By comparing the averages given in parts I and II it will be seen that when 13.5 cc. of acid were used the longer whirling periods gave higher results only at the lower speed and even then the increase was slight. The only really appreciable increase in the test obtained from a longer whirling period is shown by the figures given in part III. These

TABLE 1

The influence of the amount of acid used

Speed of centrifuge—1150 R.P.M. 10–10–5 whirling period

SAMPLE NUMBER*	11 CC. ACID	AVERAGE	13.5 CC. ACID	AVERAGE
	per cent	*per cent*	*per cent*	*per cent*
1	0.11		0.36	
	0.14	0.125	0.36	0.360
2	0.19		0.33	
	0.19	0.190	0.36	0.345
3	0.21		0.47	
	0.19	0.200	0.49	0.480
4	0.23		0.43	
	0.16	0.195	0.43	0.430
5	0.16		0.47	
	0.16	0.160	0.49	0.480
6	0.13		0.40	
	0.13	0.130	0.40	0.400
7	0.41		0.54	
	0.41	0.410	0.54	0.540
Average.....		0.202		0.434

* Sample numbers that recur in other tables refer to the same buttermilk.

data indicate that when the minimum amount of acid (11 cc.) was used, the longer whirling period resulted in an increase in the average reading from 0.201 to 0.262 per cent, an increase of about one third. However, by referring to part II of the table, it will be seen that when 13.5 cc. of acid were used at a speed of 1150 R.P.M. as high results were obtained from a 10–10–5 period of centrifuging as from a 20–20–10 period.

TABLE 2

The effect upon the results of varying the whirling period

SAMPLE NUMBER	WHIRLING PERIOD					
	5-5-5	Average	10-10-5	Average	20-20-10	Average
Part I. Speed of centrifuge—850 R.P.M.; amount of acid used—13.5 cc.						
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
4	0.38		0.45		0.44	
	0.38	0.380	0.43	0.440	0.38	0.410
6	0.40		0.40		0.40	
	0.41	0.405	0.41	0.405	0.43	0.415
7	0.47		0.52		0.56	
	0.53	0.500	0.54	0.530	0.56	0.560
8	0.70		0.76		0.72	
	0.69	0.695	0.74	0.750	0.74	0.730
9	0.38		0.38		0.45	
	0.38	0.380	0.36	0.370	0.45	0.450
10	0.37		0.35		0.42	
	0.36	0.365	0.36	0.355	0.42	0.420
Average ...		0.454		0.475		0.497
Part II. Speed of centrifuge—1150 R.P.M.; amount of acid used—13.5 cc.						
1			0.36		0.31	
			0.36	0.360	0.36	0.335
2			0.36		0.33	
			0.33	0.345	0.36	0.345
3			0.47		0.45	
			0.49	0.480	0.49	0.470
4			0.43		0.43	
			0.43	0.430	0.43	0.430
5			0.49		0.49	
			0.47	0.480	0.47	0.480
7			0.52		0.54	
			0.54	0.530	0.54	0.540
Average ...				0.438		0.433

TABLE 2—*Continued*

SAMPLE NUMBER	WHIRLING PERIOD					
	5-3-3	Average	10-10-5	Average	20-20-10	Average
Part III. Speed of centrifuge—1150 R.P.M.; amount of acid used—11 cc.						
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1			0.14		0.16	
			0.11	0.125	0.18	0.170
2			0.19		0.19	
			0.19	0.190	0.22	0.205
3			0.21		0.27	
			0.19	0.200	0.31	0.290
4			0.16		0.24	
			0.23	0.195	0.27	0.255
5			0.16		0.27	
			0.16	0.160	0.31	0.290
6			0.13		0.13	
			0.13	0.130	0.13	0.130
7			0.41		0.49	
			0.41	0.410	0.50	0.495
Average ...				0.201		0.262

3. The speed of centrifuging. To determine whether or not increasing the speed of centrifuging would increase the reading, comparisons were made between the results obtained by running the same samples at 850 R.P.M. and at 1150 R.P.M. with 10–10–5 whirling periods, and between 1150 and 1700 R.P.M. with 20–20–10 whirling periods. In all cases 13.5 cubic centimeters of sulphuric acid (the amount found to give best results) were used. It was found that when the speed of the centrifuge was increased to 1700 R.P.M. several of the test bottles were broken by the increased pressure exerted upon them. For this reason and because it was thought that any increase in reading to be obtained from the higher speed would be more noticeable with a 20–20–10 whirling period than with the shorter ones, it

TABLE 3

Table showing the effect upon the test of varying the speed of centrifuging

Part I. 10–10–5 Whirling period—13.5 cc. acid used

SAMPLE NUMBER	850 R.P.M.	AVERAGE	1150 R.P.M.	AVERAGE
	per cent	*per cent*	*per cent*	*per cent*
4	0.45		0.43	
	0.43	0.440	0.43	0.430
6	0.40		0.40	
	0.45	0.425	0.40	0.400
7	0.52		0.54	
	0.54	0.530	0.54	0.540
8	0.74		0.67	
	0.76	0.750	0.71	0.690
9	0.36		0.39	
	0.38	0.370	0.39	0.390
10	0.35		0.35	
	0.36	0.355	0.35	0.350
Average		0.478		0.467

Part II. 20–20–10 Whirling period—13.5 cc. acid used

	1150 R.P.M.	AVERAGE	1700 R.P.M.	AVERAGE
	per cent	*per cent*	*per cent*	*per cent*
1	0.36		0.35	
	0.36	0.360	0.36	0.355
2	0.33		0.31	
	0.36	0.345	0.34	0.325
3	0.45		0.45	
	0.49	0.470	0.45	0.450
4	0.43		0.43	
	0.43	0.430	0.44	0.435
5	0.47		0.49	
	0.49	0.480	0.49	0.490
7	0.54		0.53	
	0.54	0.540	0.58	0.555
Average.....		0.438		0.435

was deemed advisable to use the high speed only with the longer whirling periods.

The data in table 3 show that when using 13.5 cc. of acid and 10–10–5 whirlings as high results were obtained with a speed of 850 R.P.M. as with 1150 R.P.M. Increasing the speed to 1700 R.P.M. gave no higher results than those obtained at 1150 R.P.M., even with the 20–20–10 whirling periods.

B. A comparison of the Babcock, Normal Butyl Alcohol, and Roese-Gottlieb methods for determining the per cent of fat in buttermilk

As a result of the foregoing data, the following modification of the Babcock method was decided upon for a comparison with the Normal Butyl Alcohol and Roese-Gottlieb methods of determining the fat in buttermilk.

10-gram sample
13.5 cc. of acid (measured from a burette)
10–10–5 whirling period
1150 R.P.M.

A comparison of the results obtained by the Babcock and Roese-Gottlieb methods shows that the Babcock results are always less than those of the Roese-Gottlieb. It was noticed, however, that the difference between the two was fairly constant, being in the neighborhood of 0.2 of 1 per cent. (The average difference between the results obtained on the 12 samples is 0.2047.) In other words, practically 0.2 of 1 per cent of the fat in buttermilk is held so tightly by the milk constituents that the combined action of the acid and centrifugal force fails to liberate it. The same fact is true in testing whole milk, in which test a correction is made for the approximate 0.2 of 1 per cent fat that does not rise in the neck, by reading the fat column to the top of the meniscus.

By using 0.2 as a correction factor and adding it to the results obtained by the Babcock method, a value is obtained which is closely comparable to that obtained by the Roese-Gottlieb method.

TABLE 4

A comparison of the modified Babcock, Normal Butyl Alcohol, and Roese-Gottlieb methods for determining the fat in buttermilk

SAMPLE NUMBER	BABCOCK*	AVERAGE	BABCOCK PLUS 0.2	NORMAL BUTYL ALCOHOL	AVERAGE	ROESE-GOTTLIEB	AVERAGE
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1	0.36			0.58		0.590	
	0.36	0.360	0.56	0.58	0.580	0.572	0.5810
2	0.36			0.53		0.545	
	0.33	0.345	0.545	0.53	0.530	0.544	0.5445
3	0.49			0.69		0.667	
	0.47	0.480	0.68	0.68	0.685	0.664	0.6655
4	0.43			0.60		0.628	
	0.43	0.430	0.63	0.60	0.600	0.626	0.6270
5	0.49			0.68		0.698	
	0.47	0.480	0.68	0.68	0.680	0.685	0.6915
6	0.40			0.54		0.596	
	0.40	0.400	0.60	0.54	0.540	0.598	0.5970
7	0.54			0.72		0.759	
	0.54	0.540	0.74	0.72	0.720	0.772	0.7655
8	0.71			0.94		0.904	
	0.67	0.690	0.89	0.94	0.940	0.897	0.9005
9	0.39			0.56		0.570	
	0.39	0.390	0.59	0.55	0.555	0.570	0.5700
10	0.35			0.56		0.566	
	0.35	0.350	0.55	0.56	0.560	0.554	0.5600
11	0.44			0.62		0.662	
	0.44	0.440	0.64	0.62	0.620	0.645	0.6535
12	1.29			1.50		1.485	
	1.29	1.29	1.49	1.50	1.50	1.500	1.4925
Average		0.516	0.716		0.709		0.7207

* Procedure followed:

R.P.M.-1150
10-gram sample
18-gram 0.25 per cent skim milk bottle
13.5 cc. H_2SO_4 in burette
10-10-5 whirling periods

In addition, the data in table 4 confirm the work of Professor Mitchell (1) in that the results obtained by the Normal Butyl Alcohol method correspond closely with those obtained by chemical analysis.

DISCUSSION OF THE TESTS

The results of the work indicate that the amount of acid added is the most important factor to be considered in using the Babcock test for buttermilk. Another very important factor, which does not appear in the data presented, is the construction of the skim milk bottle used. Many bottles are so constructed that they "choke up" very easily at the base of the graduated capillary. A slight constriction at this opening will result in preventing some of the fat from rising into the neck of the bottle. By carefully selecting the test bottles and eliminating those that repeatedly "choke up" this difficulty was lessened. For this reason, in selecting bottles that are to be used in the test, choose those that have the graduations close together as this indicates a wide capillary. Too much emphasis cannot be laid upon the need of a test bottle that is properly constructed for the testing of buttermilk.

The Normal Butyl Alcohol test also is somewhat handicapped by the lack of a desirable test bottle. Otherwise the method is very successful.

DIRECTIONS FOR OPERATING THE MODIFIED BABCOCK TEST FOR BUTTERMILK

As a result of this experiment, the following modification of the Babcock test for determining the fat in buttermilk is presented:

1. If the sample contains visible granules of butterfat, it should be strained through cheesecloth, as floating granules of butter are not indicative of the exhaustiveness of churning.
2. Thoroughly mix the sample.
3. By means of a 10-gram Mojonnier pipette, measure 10 grams of the buttermilk to be tested into a skim milk bottle (use a 0.5 per cent bottle if possible).

4. Add 13.5 cc. of commercial sulphuric acid (having a specific gravity of 1.82–1.83) from a burette or 14 cc. from an acid measure, and mix well.

5. Centrifuge at a speed of about 1000 R.P.M. for ten minutes.

6. Fill to base of the neck of bottle with hot water and whirl for ten minutes.

7. Finish filling bottle with hot water and whirl for five minutes.

8. Allow to remain five minutes in a hot water bath having a temperature of 135–140°F.

9. Read to the top of the meniscus and multiply the result by 1.8. (The fat column should be a dark amber color. If it is a straw yellow color, the amount of acid used should be increased.)

10. Add the correction factor of 0.2.

PRECAUTIONS

1. Be sure the sample is well mixed before pipetting.

2. Be sure the acid is of proper strength. If a deep amber colored fat column does not result, increase the amount of acid used.

3. Add only enough water the first time to raise the mixture in the bottle up to the point where the graduated neck is joined to the shoulder of the bottle. If a little clearance is left between the top of the liquid in the bottle and the opening into the graduated portion of the neck, the danger of "choking" the neck of the bottle will be diminished, as the final addition of water will cause only the collected fat to rise into the graduated portion of the neck.

4. Mark the bottles that "choke up" and eliminate those that repeat.

CONCLUSIONS

1. The amount of acid used has a very important effect upon the results obtained in the Babcock method of testing buttermilk.

2. The extension of the whirling period beyond the 10–10–5 minute periods has no appreciable effect upon the result obtained in the Babcock method of testing buttermilk.

3. Increasing the speed of the centrifuge above 900–1000 revolutions per minute will not increase the readings obtained in the Babcock method of testing buttermilk.

4. With the proper modifications of the Babcock test and with the addition of a correction factor of 0.2, results can be obtained that will conform closely to the Roese-Gottlieb determination.

5. The results of the Normal Butyl Alcohol method of testing buttermilk check closely with the Roese-Gottlieb determination.

REFERENCES

(1) Chicago Dairy Produce, December 31, 1921.
(2) Method of Analysis, A. O. A. C., 1920.

COMPARISON OF METHODS OF READING CREAM TESTS

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There has been and still is quite a wide difference of opinion in regard to the manner of reading the Babcock cream test. Even in the last publication of the Official Methods of Analysis of the Association of Official Agricultural Chemists, no specific directions are given concerning the manner of reading the finished test. This text refers the analyst to either Farrington and Woll or to Van Slyke. This is a particularly unfortunate statement since the two references cited do not agree as to the manner of reading cream tests. We find that in Farrington and Woll the cream tester is directed to read the finished test by measuring the fat column the same as for a milk test—that is, from the extreme low point of the lower meniscus to the extreme upper point of the top meniscus, while Van Slyke states that the top meniscus of the finished test should be flattened by the use of glymol, separator oil, amyl alcohol, or fat saturated alcohol. Neither of these authors show any comparison of their method with any of the extraction methods as proof of their own.

In consulting other authors and bulletins we find that several other methods are advised, very few of which are actually supported by comparison either with the Roese Gottleib (a recognized official and accurate method) or any continuous extraction method.

Hunziker in his texts advises the use of glymol to flatten the upper meniscus or in its absence to include one-third of the upper meniscus in the reading.

Wing in his Manual of Milk Products advises Farrington and Woll's method of reading to the extremes of the fat column.

McKay and Larsen suggest the use of light mineral oil, Troy and McInerney, red reader (glymol), Fisk, glymol, and Babcock and Farrington fat-saturated-alcohol, to flatten the upper meniscus and insure an accurate reading.

Webster introduces further complications by stating that the cream test should be read from the bottom of the fat column to the extreme top and then to deduct four-fifths of the depth of the top meniscus from this reading for an 18 gram charge. In the case of a 9 gram charge used in an 18 gram bottle he states that 0.2 should be added after the reading is doubled.

Shaw in the Government Bulletin entitled, "Chemical Testing of Milk and Cream" directs the tester to read the cream test from the bottom of the lower meniscus to the bottom of the upper.

Erf and Cunningham agree with Indiana Bulletin 145 that the use of glymol gives the most accurate results and in the absence of glymol the test should be read from the lowest point of the fat column to the bottom of the clear part of the upper meniscus.

Gregory and Hammond in the recent Purdue Circular No. 78 Revised, use Hunziker's method of including one-third the top meniscus or flattening the meniscus with glymol.

In all of these tests the lack of substantial data in support of the various methods of reading is striking. It would seem with so many opinions in the field that authorities using a method which does not agree with another would show data to prove their points, but seemingly little work has been done in actually comparing these different methods with the extraction methods which are known to be accurate. In some cases these comparisons were probably made but the results are very hard to find.

Siegmund and Craig of Baltimore claim that the tests for cream using the glymol method were about 1.5 per cent too high and that by increasing the speed of the centrifuge to twice the correct figure they were able to obtain practically indentical results between the Babcock and extraction methods.

Ross and McInerney in Cornell Bulletin No. 337 advise the use of glymol and give figures comparing the readings using glymol with readings without glymol. They find that the glymol readings fall under the other readings about 1.5 per cent on 6 inch bottles and 1 per cent on 9 inch bottles. They do not state what method of reading they used on the tests where no glymol was used but it is presumed that they included one-third of the upper meniscus according to Hunziker whom they refer to.

They also, in the same bulletin, give the results of the analysis of 64 cream samples by both the Babcock glymol and a method they term chemical, presumably an extraction method. The results of these analyses check very closely, in fact only 8 varied more than 0.5 per cent which is the finest division on the usual cream bottles.

There are probably other methods of reading cream tests and quite possibly other data in support of the tests but they have not come to the writer's attention.

There seems to be no reason why some definite and specific method, supported by substantial data from various sources, cannot be written into the "Official Methods" and put an end once and for all to the confusing differences of opinion now existing. It would seem that on the face of it the methods using a "meniscus remover" or "red reader" would give more consistant results than any method which adds or subtracts a fraction of the upper meniscus, since the depth of meniscus varies with the diameter of the neck and the meniscus outline is far from distinct.

Believing that this subject should bear investigation and further, that a small number of comparisons made at several different places by different investigators are more desirable than a large number run at one place we therefore submit the following with the suggestion that it be further tried elsewhere.

The following table shows the results of our work.

SAMPLE	TO BOTTOM OF UPPER MENISCUS	TO EXTREME TOP OF UPPER MENISCUS	USING GLYMOL BOTTLE A	USING ALCOHOL FAT-SATURATED BOTTLE B	ONE-THIRD OF MENISCUS	ROSSE GOTTLIEB-OFFICIAL
1 A	18.50	20.00	18.75		19.00	18.80
1 B	18.50	20.00		19.00		18.71
2 A	20.00	21.50	20.00		20.50	19.90
2 B	20.00	21.50		20.50		19.96
3 A	29.50	31.00	29.50		30.00	29.21
3 B	29.50	31.00		30.00		29.22
4 A	38.00	38.75	38.00		38.45	37.62
4 B	38.50	39.25		38.50		37.68
5 A	33.50	34.25	32.75		33.45	32.14
5 B	33.25	34.00		33.00		32.16
6 A	16.50	18.00	16.50		17.00	16.30
6 B	16.50	18.00		17.00		16.34
7 A	22.00	23.50	22.00		22.50	21.74
7 B	22.00	23.50		22.25		21.82
8 A	26.50	27.50	26.50		26.83	26.13
8 B	26.50	27.50		27.00		26.14
9 A	35.50	36.25	35.25		35.75	34.87
9 B	35.50	36.25		36.00		34.95
10 A	25.25	26.50	25.50		25.50	25.08
10 B	25.25	26.50		25.75		25.12
Average	26.51	27.72	26.47	26.90	26.90	26.19
Variation....	+0.32	+1.53	+0.28	+0.71	+0.71	0

PROCEDURE

The ten samples of cream were obtained by separating evenings milk obtaining a portion of cream testing about 38 per cent. This portion was then used in preparing samples of 10 different tests by diluting with various amounts of whole milk. These samples were held at 40°F. until the following morning when the

analyses were made after warming the cream to 100°F. and thoroughly mixing by pouring into individual dry beakers.

The cream was weighed on a Troemner, agate knife edge balance to the nearest 0.005 gram. Nine gram 50 per cent, 6 inch cream bottles were used in all cases with a 9 gram charge and an addition of 9 cc. of distilled water. The amount of acid (1.822 specific gravity) was determined by trial and no results were included that did not show an absolutely clear and perfect fat column. Amounts used varied from 17.0 to 18.0 cc. depending on test of cream. The centrifuge was an electric machine heated electrically to 145°F., diameter of wheel 15 inches and run at a speed of 900 R.P.M. Centrifuge periods of 5, 2 and 1 minutes were used with two additions of distilled water at 180°F. The bottles were tempered for 4 to 5 minutes at 138°–42°F. and read at these temperatures, direct from the bath. Readings for the first and second columns of the table were made at the same time after which the bottles were returned to the bath and retempered for a minute or two. Glymol colored with alkanet was then added to the A bottles and the test reread while fat-saturated-alcohol colored with alizarine was added to the B bottles in a similar manner. These additions were made carefully down the side of the tube to a depth of about $\frac{3}{8}$ inch.

The readings in column 5, including one-third the meniscus were obtained as follows: the test for each sample in columns 1 and 2 were averaged and the variations due to the depth of meniscus obtained by difference after which one-third of this difference was added to the average test obtained in column 1.

The results in column 6 were obtained following the Roese-Gottlieb method exactly as outlined in the Official Methods, with the exception that Mojonnier extraction flasks were used in place of a Röhrig tube. Both ethers were redistilled at low temperatures before use and the flasks extracted with 2–25 cc. charges of each ether followed by a final 15 cc. charge of each. The flasks containing the fat were dried to constant weight.

INTERPRETATION

Our results show that the method using glymol checks closest with the Roese-Gottlieb; the variation being plus 0.28 per cent while the method of Shaw, reading from the bottom of the lower to the extreme low point of the upper, gives practically identical results, the variation being plus 0.32 per cent.

The other methods used however are more than 0.5 per cent out of the way. This was a surprise in the case of the fat-saturated-alcohol, which varied plus 0.71 per cent. It was thought that this method would check rather closely with the glymol. It was noticed in all the bottles, however, that the alcohol did not give as flat a top line as the glymol, the tendency being to change the concave of the meniscus to a convex line between the fat and the alcohol. We read to the top of this convex surface which may explain this result.

The method recommended by Hunziker and quoted by others of including one-third of the meniscus, gave results which were high by plus 0.71 per cent being the same as those obtained with the alcohol.

Basing our opinion on these results it would seem that either Shaw's method or the glymol method of reading cream tests is the most accurate. However, since there are various types of bottles in use and various methods of treating the charge as regards the amount of acid, more work should be done to justify the above statement.

THE RELATION OF THE OXIDIZABILITY VALUE AND THE AMINO AND AMMONIA NITROGEN CONTENT TO THE QUALITY OF CREAM AND BUTTER

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Previous work on the relation of amino nitrogen and ammonia to total nitrogen[1, 2] and on the volatile oxidizable substances[3] in cream and butter showed that these determinations might give some indication of the kind of cream used in making a given sample of butter. Inasmuch as this work had been confined to one creamery in the Middle West and one in the East, it seemed advisable to make investigations on samples which represented a greater portion of the butter that enters into commerce. Accordingly, representative samples of cream and butter from eleven different creameries throughout the Central States and two in the East were collected and forwarded to Washington for chemical examination.[4]

Portions of each sample of cream were treated with acetic acid and picric acid, filtered and the filtrates, together with some of the cream preserved with formaldehyde, were sent to Washington for determination of total nitrogen, and amino nitrogen and

[1] A method for the determination of amino nitrogen and ammonia in cream and butter. Journal of Dairy Science, v, no. 4, July, 1922.

[2] Some determinations on the soluble nitrogen compounds in cream and butter. Journal of Dairy Science vi, no. 3. May, 1923.

[3] The volatile acids and the volatile oxidizable substances of cream and experimental butter. Journal of Dairy Science, iv, no. 6, p. 521, 1921.

[4] All field work, including collection and preparation of samples, and all microscopic counts, were made by Mr. W. R. North, Jr., Mr. G. F. Reddish, and Dr. Edwin LeFevre of this Bureau, and acknowledgment is hereby made.

Appreciation is also expressed to Mr. J. I. Palmore, Miss D. B. Scott and Mr. L. Jones, for assistance in chemical determinations.

ammonia. By this procedure the amino nitrogen and ammonia found represented the amount actually present at the time the cream was sampled. Duplicate portions of the cream were also sent by mail, without refrigeration, to the nearby Chicago Station

TABLE 1

Plant 1

SAMPLE NUMBER	GRADE OF CREAM	SCORE OF BUTTER	OXIDIZABILITY VALUE BUTTER	AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				Cream	Butter
1	Sweet	94	1.3	1.5	1.2
2	Sweet	94	1.3	1.7	1.3
3	Sweet	94	1.2	1.7	0.7
4	Sweet	94	0.7	1.9	0.7
5	Sweet	93½	1.9	2.0	1.8
6	Sweet	93½	0.9	1.1	1.0
7	Sweet	94	0.7	1.3	1.4
Average.....		$93\frac{6}{7}$	1.1	1.6	1.2

Cream contained practically no yeasts or oidia.

TABLE 2

Plant 2

SAMPLE NUMBER	GRADE OF CREAM	SCORE OF BUTTER	OXIDIZABILITY VALUE BUTTER	AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				Cream	Butter
1	Sweet	93	0.1	1.9	0.9
2	Sweet	93½	0.3	1.6	0.7
3	Sweet	94	0.3	1.9	0.4
4	Sweet	93	0.5	2.1	1.1
5	Sweet	93	0.6	1.5	0.9
Average.....		$93\frac{3}{10}$	0.4	1.8	0.8

Cream contained practically no yeasts or oidia.

for determination of oxidizability value. Since these samples contained no preservative, the time between collection of sample and analysis should be taken into consideration. This time, in the majority of cases, was from one to three days, although one sample was seven days, two samples six days, one sample five days,

and five samples four days in transit. However, since some samples only one day in transit gave higher oxidizability values than others four days, this delay does not seem very significant.

TABLE 3

Plant 3

SAMPLE NUMBER	GRADE OF CREAM	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
			Cream	Butter	Cream	Butter
1	1	89 s		1.3	5.5	3.0
2	1	89 s		2.4	5.8	2.5
Average		89		1.8	5.6	2.7

s = Salted.

Yeast count on cream varied from 1,600,000 to 4,400,000.

Oidia count on cream varied from 230,000 to 420,000.

TABLE 4

Plant 4

SAMPLE NUMBER	GRADE OF CREAM	CREAM SAMPLE FOR OXIDIZABILITY VALUE IN TRANSIT	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				Cream	Butter	Cream	Butter
		days					
1	1	3	89½ (89) s	50.4	1.8	5.5	3.4
2	1	3	90 (89) s	46.1	1.2	6.4	4.1
3	1	1	91 (88) s	39.7	4.1	6.6	3.3
4	1	2	89 (87½) s	47.7	3.2	6.9	3.0
5	2	3	(85) u	53.7	7.7	7.7	3.5
6	2	3	(84) u	66.9	4.1	7.7	4.4
7	2	1	(85) u	52.8	11.9	8.0	5.5
8	2	2	(84) u	69.7	11.2	9.1	5.3
First grade average.....			88.4	46.0	2.6	6.3	3.4
Second grade average.....			84.5	60.8	8.7	8.1	4.7

s = Salted.

u = Unsalted.

Yeast count on cream varied from 4, 375,000 to 9,500,000.

Oidia count on cream varied from 625,000 to 1,825,000.

Butter scores in parenthesis were given by Mr. G. R. Campbell of Dairy Division at the time the butter samples were analyzed.

The other scores in this table were on duplicate portions kept in cold storage 25 days.

The corresponding samples of butter were forwarded to Washington in refrigerator cars, the samples reaching their destination in from 13 to 43 days, with the exception of those

TABLE 5

Plant 5

SAMPLE NUMBER	GRADE OF CREAM	CREAM SAMPLE FOR OXIDIZABILITY VALUE IN TRANSIT	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				Cream	Butter	Cream	Butter
		days					
1	1	2	89½ u	43.2	3.8	6.4	4.9
2	1	1	89½ u	48.0	5.6	6.8	4.8
3	1	1	90 u	43.8	4.3	7.7	4.6
4	2	1	88 u	69.8	5.3	8.7	5.2
5	2	2	88 u	52.1	5.7	9.0	5.7
First grade average.....			89.7	45.0	4.6	7.0	4.8
Second grade average.....			88	61.0	5.5	8.8	5.4

u = Unsalted.
Yeast count on cream varied from 3,300,000 to 5,475,000.
Oidia count on cream varied from 950,000 to 2,925,000.

TABLE 6

Plant 6

SAMPLE NUMBER	GRADE OF CREAM	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
			Cream	Butter	Cream	Butter
1	1	92s		4.7	7.0	4.6
2	1	92s		3.9	7.1	5.2
3	2	89u		9.0	8.4	5.8
4	2	90u		5.9	9.1	4.6
First grade average..		92		4.3	7.0	4.9
Second grade average		89½		7.4	8.7	5.2

s = Salted.
u = Unsalted.
Yeast count on cream varied from 340,000 to 1,510,000.
Oidia count on cream varied from 158,000 to 830,000.

from plant no. 9, which were delayed 88 days. As soon as the butters were received they were scored by Mr. S. C. Thompson of the Dairy Division of the United States Department of Agricul-

TABLE 7

Plant 7

SAMPLE NUMBER	GRADE OF CREAM	CREAM SAMPLE FOR OXIDIZABILITY VALUE IN TRANSIT	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				Cream	Butter	Cream	Butter
		days					
1	1	3	91s	52.5	5.3	6.7	6.1
2	1	3	91s	58.6	4.7	7.2	6.2
3	1	2	89s	49.3	4.7	7.4	5.6
4	1	4	90u	61.4	5.9	7.6	6.8
5	1		90s		6.5	7.8	5.1
6	1	3	90s	54.7	5.3	7.8	5.3
7	1	3	89s	32.6	5.8	8.0	4.3
8	2	3	88u	65.9	6.5	8.5	7.5
9	2	2	88u	54.4	10.3	8.8	5.8
10	2	3	89u	54.1	8.8	8.8	5.8
11	2	4	88s	79.7	6.5	8.9	4.2
First grade average			90	51.5	5.4	7.5	5.6
Second grade average			88¼	63.5	8.0	8.7	5.8

s = Salted.
u = Unsalted.
Yeast count on cream varied from 4,700,000 to 7,500,000.
Oidia count on cream varied from 1,300,000 to 2,350,000.

TABLE 8

Plant 8

SAMPLE NUMBER	GRADE OF CREAM	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
			Cream	Butter	Cream	Butter
1	1	91s		2.9	6.8	5.0
2	1	89s		3.5	7.8	4.2
3	1	91s		3.5	8.0	4.9
4	2	89s		8.8	8.6	5.1
5	1	89s		1.8	8.7	4.8
First grade average. .		90		2.9	7.8	4.7
Second grade average		89		8.8	8.6	5.1

s = Salted.
Yeast count on cream varied from 140,000 to 1,650,000.
Oidia count on cream varied from less than 5,000 to 170,000.

TABLE 9

Plant 9

SAMPLE NUMBER	GRADE OF CREAM	CREAM SAMPLE FOR OXIDIZABILITY VALUE IN TRANSIT	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AT PER CENT OF TOTAL NITROGEN	
				Cream	Butter	Cream	Butter
		days					
1	1		90s		5.3	6.5	3.2
2	1		90s		3.7	7.1	3.8
3	1	3	89s	46.7	6.2	7.9	5.7
4	2		85*u		9.4	8.4	15.6*
5	2	5	83*u	46.0	9.1	9.3	13.8*
6	2	3	88*u	67.8	8.2	10.5	9.3*
First grade average.....			89¾	46.7	5.1	7.2	4.2
Second grade average			85¼*	56.9	8.9*	9.4	12.9

s = Salted.

u = Unsalted.

* The samples of butter from the above creamery were delayed in transit 88 days, which is probably the cause of the unusual results on the unsalted butters.

Yeast count on cream varied from 1,750,000 to 4,900,000.

Oidia count on cream varied from 900,000 to 3,550,000.

TABLE 10

Plant 10

SAMPLE NUMBER	GRADE OF CREAM	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
			Cream	Butter	Cream	Butter
1	1				7.3	
2	1	87s		4.3	7.7	4.7
3	1	s		0.3	8.3	4.7
4	2				8.6	
5	2	s		3.4	8.8	6.1
6	1	86s		4.4	9.4	6.1
7	2				10.5	
First grade average. ...				3.0	8.2	5.2
Second grade average ..				3.4	9.3	6.1

s = Salted.

Yeast count on cream varied from 760,000 to 2,730,000.

Oidia count on cream varied from 60,000 to 410,000.

ture and analyzed by the same procedure used in previous work.[1,2,3] Water, fat and total nitrogen were determined on all the butter samples and inasmuch as these results were normal they

TABLE 11

Plant 11

SAMPLE NUMBER	GRADE OF CREAM	CREAM SAMPLE FOR OXIDIZABILITY VALUE IN TRANSIT	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				Cream	Butter	Cream	Butter
		days					
1	1	2	90s	73.6	4.1	7.0	5.0
2	1	2	89s	69.8	5.6	7.4	5.4
3	1	7	89s	74.5	4.1	7.5	5.4
4	1	3	89s	87.2	4.3	8.7	4.9
5	2	6	88s	88.6	4.1	11.7	6.0
6	2	3	88s	85.1	5.3	12.2	4.7
First grade average.....			89½	76.3	4.5	7.6	5.2
Second grade average.....			88	86.8	4.7	11.9	5.3

s = Salted.

Yeast count on cream varied from 3,250,000 to 13,550,000.

Oidia count on cream varied from 1,900,000 to 4,500,000.

TABLE 12

Plant 12

SAMPLE NUMBER	GRADE OF CREAM	CREAM SAMPLE FOR OXIDIZABILITY VALUE IN TRANSIT	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				Cream	Butter	Cream	Butter
		days					
1	1	3	88s	49.3	6.8	7.5	4.2
2	1	2	90s	36.8	7.1	8.6	3.7
3	1	3	89s	47.3	6.2	8.9	4.4
4	1	2	90s	41.9	6.8	9.2	4.1
5	2	4	87u	45.7	8.7	11.9	6.7
6	2		88u		8.5	12.2	6.8
First grade average.....			89½	43.8	6.7	8.5	4.1
Second grade average.....			87½	45.7	8.6	12.0	6.7

s = Salted.

u = Unsalted.

Yeast count on cream varied from 4,000,000 to 7,975,000.

Oidia count on cream varied from 1,175,000 to 3,175,000.

have not been recorded here. The total nitrogen varied from 0.039 to 0.121 per cent. The results obtained for oxidizability value and amino nitrogen and ammonia as per cent of total nitrogen on cream and butter and the score of the butter have been tabulated, the samples from each creamery being arranged according to ascending value for amino nitrogen and ammonia as per cent of total nitrogen on the cream. Both salted and unsalted butters were examined as indicated in the tables. For

TABLE 13

Plant 18

SAMPLE NUMBER	GRADE OF CREAM	CREAM SAMPLE FOR OXIDIZABILITY VALUE IN TRANSIT	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
				cream	butter	cream	butter
		days					
1	1	2	90u	62.7	3.7	9.0	5.4
2	1	4	90½u	67.8	3.8	9.2	5.8
3	1	2	89u	68.5	4.8	9.8	7.2
4	1	1	90u	46.1	4.1	10.0	5.8
5	1		90u		3.8	10.0	7.1
6	2	4	87s	54.1	4.8	11.5	5.6
7	2		87s		4.3	13.1	4.3
8	2	3	87s	44.2	3.5	13.3	6.0
First grade average.....			$89\frac{9}{10}$	61.3	4.0	9.6	6.3
Second grade average.....			87	49.1	4.2	12.6	5.3

s = Salted.
u = Unsalted.
Yeast count on cream varied from 5,500,000 to 9,900,000.
Oidia count on cream varied from 1,650,000 to 5,250,000.

easy comparison, the averages for each plant have been assembled as shown in table 14. The distinction as to grades of cream refers in each case to the grading of the plant itself. Butter is described as first or second grade to show that it was made from a first or a second grade cream in each case and without consideration of score given to the butter.

Plants no. 1 and no. 2 were receiving sweet cream of high quality, practically no yeasts or oidia[5] being found in all the

[5] The determination of yeasts and oidia in cream and butter, H. W. Redfield. Journal of Dairy Science, v, no. 1, January, 1922.

samples. All the butter samples from no. 1 were from cream churned without the addition of starter, with the exception of sample no. 5. Of the butter samples from plant no. 2, all were

TABLE 14

Average results on all plants

PLANT NUMBER	SCORE OF BUTTER	OXIDIZABILITY VALUE		AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	
		Cream	Butter	Cream	Butter
First grade					
1	93⅞		1.1	1.6	1.2
2	93 3/10		0.4	1.8	0.8
3	89		1.8	5.6	2.7
4	88 4/10	46.0	2.6	6.3	3.4
5	89 7/10	45.0	4.6	7.0	4.8
6	92		4.3	7.0	4.9
7	90	51.5	5.4	7.5	5.6
8	90		2.9	7.8	4.7
9	89⅞	46.7	5.1	7.2	4.2
10			3.0	8.2	5.2
11	89¼	76.3	4.5	7.6	5.2
12	89¼	43.8	6.7	8.5	4.1
13	89 9/10	61.3	4.0	9.6	6.3
Second grade					
1					
2					
3					
4	84½	60.8	8.7	8.1	4.7
5	88	61.0	5.5	8.8	5.4
6	89½		7.4	8.7	5.2
7	88¼	63.5	8.0	8.7	5.8
8	89		8.8	8.6	5.1
9	85½	56.9	8.9*	9.4	12.9*
10			3.4	9.3	6.1
11	88	86.8	4.7	11.9	5.3
12	87½	45.7	8.6	12.0	6.7
13	87	49.1	4.2	12.6	5.3

* See footnote plant no. 9, table 9.

from cream containing starter except no. 2. The butter from both of these plants scored 93 to 94. The average oxidizability value on the butter was 1.1 and 0.4. The average amino nitro-

gen and ammonia as per cent of the total nitrogen was 1.6 and 1.8 on the cream and 1.2 and 0.8 on the butter from plants no. 1 and no. 2, respectively.

Plant no. 3 was a small creamery receiving cream from short hauls; however, the cream was sour and was pasteurized and churned without having the acidity reduced. The cream contained from 1,600,000 to 4,400,000 yeasts and from 230,000 to 420,000 oidia. The average oxidizability value on the butter was 1.8. The average amino nitrogen and ammonia as per cent

TABLE 15

Amino nitrogen and ammonia as per cent of total nitrogen, showing range for first and second grades of cream

PLANT NUMBER	FIRST GRADE		SECOND GRADE	
	Minimum	Maximum	Minimum	Maximum
1	1.1	2.0		
2	1.5	2.1		
3	5.5	5.8		
4	5.5	6.9	7.7	9.1
5	6.4	7.7	8.7	9.0
6	7.0	7.1	8.4	9.1
7	6.7	8.0	8.5	8.9
8	6.8	8.0 (8.7)	8.6	
9	6.5	7.9	8.4	10.5
10	7.3	8.3 (9.4)	8.6	10.5
11	7.0	8.7	11.7	12.2
12	7.5	9.2	11.9	12.2
13	9.0	10.0	11.5	13.3

of the total nitrogen was 5.6 on the cream and 2.7 on the butter, and the score of the butter was 89.

Plant no. 8 received sour cream from short distances, the samples collected containing from 140,000 to 1,650,000 yeasts and from less than 5,000 to 170,000 oidia. The acidity of the cream was reduced to about 0.4 per cent before churning, which is higher than the general practice among centralizers. Only one of the samples of cream from this plant was classed as second grade. The average oxidizability value on the first grade butters was 2.9, and 8.8 on the second grade sample. The average amino

nitrogen and ammonia as per cent of the total nitrogen on the first grade samples was 7.8 for the cream and 4.7 for the butter, and for the second grade sample, 8.6 and 5.1, respectively. The

TABLE 16

Showing results of chemical and bacteriological examinations of cream from plants no. 3 and no. 8.

SAMPLE NUMBER	AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN	AGE OF CREAM	MICROSCOPIC COUNT		DESCRIPTION OF SAMPLE
			yeasts	*oidia*	
		days			
1	2.7	7	12,000,000	500,000	Low acid; slightly stale
2	3.7	3	450,000	270,000	Low acid; clean flavor
3	4.0	4	820,000	215,000	
4	4.1	7	280,000	2,630,000	Medium acid; slightly stale
5	4.6	4	100,000	680,000	Clean flavor; low acid
6	4.7	4	650,000	130,000	Clean flavor; low acid
7	4.9	5	670,000	940,000	
8	5.3	3	130,000	20,000	Medium acid; clean flavor
9	5.4	3	440,000	340,000	Composite of 13 batch samples
10	5.5		1,600,000	230,000	Medium high acid; not appreciably stale
11	5.8		4,400,000	420,000	Acidity 0.65
12	6.0	6	4,500,000	950,000	Medium acid; clean flavor
13	6.3	4	500,000	145,000	
14	6.5		850,000	90,000	Acidity 0.82
15	6.6		760,000	75,000	First grade
16	6.8	2	140,000	−5,000	Acidity 0.65
17	6.9	3	370,000	15,000	Acidity 0.81
18	7.2	6	200,000	860,000	Medium acid; clean flavor; lumpy
19	7.8	3	600,000	15,000	Acidity 0.89.
20	8.0		800,000	150,000	First grade; acidity 0.89
21	8.6		1,650,000	170,000	Second grade
22	8.7		910,000	50,000	First grade; acidity 0.84
23	8.7	3	2,600,000	150,000	Whey cream.
24	10.3		1,000,000	85,000	Acidity 0.78

second grade butter scored 89 and the first grade samples scored from 89 to 91.

All of the remaining plants belong to the centralizer class, receiving sour cream, some of which contained more or less off

flavors. This cream was divided into first and second grade, each grade being churned separately. Samples of cream and butter of both grades were secured during the months of June, July and August, 1921, from each of these plants, the yeast count on the cream varying from 140,000 to 13,550,000 and the oidia count from 60,000 to 5,250,000. The oxidizability value was high on all the samples of cream examined, averaging from 43.8 to 76.3 for the first grade samples and from 45.7 to 86.8 for the second grade samples. The values on the butters averaged from 2.6 to 6.7 for the first grade and from 3.4 to 8.9 for the second grade samples. With the exception of the results from plant no. 13,

TABLE 17

Showing increase in amino nitrogen and ammonia as per cent of total nitrogen on cream samples sent through mail and containing no preservative

SAMPLE NUMBER	DAYS HELD IN MAIL	AMINO NITROGEN AND AMMONIA AS PER CENT OF TOTAL NITROGEN		INCREASE
		A	B	
1	3	7.9	12.3	4.4
2	3	10.5	13.4	2.9
3	4*	9.2	13.5	4.3
4	4*	11.5	15.7	4.2
5	3	7.6	13.2	5.6
6	3	8.9	11.0	2.1

* Two days in ice box after received.

the average oxidizability value was higher on the second grade than on the first grade samples from each plant, respectively.

When the samples from each plant are arranged according to ascending values for amino nitrogen and ammonia as per cent of total nitrogen on the cream, it is observed that the first and second grades are separated. With only two exceptions, sample no. 5, from plant no. 8, and sample no. 6, from plant no. 10, the second grade creams have a higher figure for amino nitrogen and ammonia as per cent of the total nitrogen than the first grade creams from the corresponding plant. The significance of this fact is that in samples of cream which, according to the judgment of cream graders, will produce an inferior quality of

butter, there are present increased amounts of decomposition products measurable by chemical means.

Table 15 shows the maximum and minimum figure for first and second grades of cream from each plant. It is evident from these results that different cream graders working under different conditions will have different standard qualities as measured by the amino nitrogen and ammonia as per cent of the total nitrogen, for separating first and second grade cream. The standard any one grader will have will depend primarily upon the kind of

TABLE 18

Showing results on authentic samples of milk from individual cows

NUMBER	QUANTITY OF MILK	PERIOD IN LACTATION	TOTAL NITROGEN	AMINO NITROGEN AND AMMONIA AS PERCENT OF TOTAL NITROGEN
	lbs.	*months*	*per cent*	
1	12.9	4	0.504	2.2
2	29.0		0.420	2.3
3	8.5	10	0.460	2.9
4	11.0	7	0.415	3.3
5	18.6	4	0.443	3.0
6	8.5	10	0.471	3.6
7		4	0.448	2.7
8	(mixed sample from 2 cows)		0.437	2.4
9	9.5	2	0.392	2.7
10		2	0.415	3.2
11	12	2	0.521	2.6
Average				2.8
Maximum				3.6
Minimum				2.2

cream he receives and the grade of butter he desires to manufacture.

That these samples of cream containing the higher percentage of decomposition products actually produced inferior butter is shown by the fact that the average score on the second grade samples in every case is lower than on the first grade samples. In a general way, the amino nitrogen and ammonia as per cent of the total nitrogen on the butter agrees with that on the cream from which the butter was made. The fact that there is not a

strict correlation between cream and the resulting butter may be attributed to the details of manufacture, particularly the amount of starter added and the thoroughness of washing out the buttermilk. It is noticeable, however, that there is a wide difference between the results on the high scoring butters from plants nos. 1 and 2, and the results on the butters from the centralizing plants. The highest figure on the high grade butters, scoring 93 to 94, was 1.8, while on the remaining samples with the lower scores the results varied from 2.5 to 7.2 for first grade and from 3.5 to 7.5 for second grade butters.

The above results show that the amino nitrogen and ammonia as per cent of the total nitrogen gives a good indication of the quality of a given sample of cream for butter making. While the above recorded samples were being collected at plants no. 3 and no. 8, more samples of cream were taken from individual cans from farmers delivering their cream at known intervals. The results of the examination of these samples are shown in table 16, the samples being arranged according to increasing values for amino nitrogen and ammonia as per cent of the total nitrogen. This figure is not correlated with the age of the cream or the microscopic count of yeasts and oidia. It seems that the temperature at which cream is held is a more important factor than time in controlling decomposition.

In order to show the approximate rate of increase of amino nitrogen and ammonia under the conditions encountered in this work, duplicate portions of the cream samples containing no preservative, collected at plants no. 6, no. 7 and no. 13, were forwarded to Washington. Column A, table 17, represents the condition of sample at the time it was sampled at the plant, and column B at the time the samples were examined at Washington, the number of days the samples were held being shown in column 2. The average increase of the amino nitrogen and ammonia under these conditions was found to be about 1 per cent of the total nitrogen for each day the samples were held.

Table 18 shows the amino nitrogen and ammonia as per cent of the total nitrogen on 11 authentic samples of milk from individual cows. Samples nos. 1 to 10, inclusive, were from

Holstein cows milked three times a day and the samples were taken at the mid-day milking. Picric acid and acetic acid were added to the milk within 30 minutes of the time the milk was drawn and all solutions were filtered within two and one-half hours. The cows were being fed on a balanced ration of shorts, grain, cottonseed meal, silage, etc., and a small amount of pasturage. Sample no. 11 was from the morning milking of a Jersey cow fed approximately as the above but being milked only twice a day. The amino nitrogen and ammonia as per cent of the total nitrogen on these samples varied from 2.2 to 3.6, the average being 2.8.

SUMMARY.

Representative samples of cream and butter from thirteen different creameries were examined and it was found that the second grade cream contained a greater percentage of the total nitrogen present as amino nitrogen and ammonia than the first grade cream from the corresponding plants. This value averaged from 1.6 to 9.6 on cream producing first grade butter and 8.1 to 12.6 on cream that produced second grade butter. The results on the corresponding butters varied from 0.8 to 6.3 for the first grade and from 4.7 to 6.7 for the second grade samples. The butter from the cream containing the smaller amounts of amino nitrogen and ammonia as per cent of the total nitrogen scored from 93 to 94, while there was a general decrease in score on the butters from the cream having the higher value. The oxidizability value varied from 0.4 to 6.7 on the first grade butter and from 3.4 to 8.8 on the second grade butter, being higher, in general, on samples having the lower scores. Eleven authentic samples of fresh milk from individual cows gave values for amino nitrogen and ammonia as per cent of the total nitrogen varying from 2.2 to 3.6.

A STUDY OF THE ACTION OF CERTAIN BACTERIA, YEASTS AND MOLDS ON THE KEEPING QUALITY OF BUTTER IN COLD STORAGE[1]

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The development of the practice of cold-storing butter, manufactured during the Spring and early Summer, for sale during the Winter months has resulted in much work being done to determine the factors which influence the keeping quality of butter in cold storage; for, to the consumer, butter is as old as it tastes, whether it is a week old or six months old is immaterial to him, and if the butter has deteriorated in flavor it means a consequent depreciation of its commercial value.

Sayer, Rahn and Farrand 1908 (23) reviewed the literature relative to the keeping qualities of butter and Rahn and his co-workers 1909 (18) stated "It may and possibly is the type of microörganism present that is of importance, and the enzyme or disintegration products therefrom." Rogers and co-workers 1912 (20) stated "Butter frequently undergoes marked changes, even when stored at very low temperatures. These changes are more marked as the acidity of the cream from which the butter is made increases." Brown 1915 (3) concluded that the casein in butter during storage is slowly broken down into amino acids and ammonia. Dyer 1916 (4) stated "The production of off flavors so commonly met with in cold storage butter is attributable to a chemical change expressed through a slow oxidation progressing in some one or more of the non-fatty substances occurring in the butter. The extent of the chemical change is

[1] A summary of work carried out in partial fulfilment of the requirements for the Degree of Doctor of Philosophy, Iowa State College.

directly proportional to the quantity of acid present in the cream from which the butter was prepared." Hammer 1917 (7) reviewed the literature upon the production of fishy flavor in milk and butter and stated that *Bact. ichthyosmius* failed to produce fishiness when inoculated into butter. Washburn and Dahlberg 1917 (25) concluded that little if any relationship existed between the bacteria, the acidity and the score of the butter. Russell and Hastings 1920 (22) stated "In general it may be said that any and all types of organisms in the cream affect the keeping quality of the butter, to a greater or less extent, in an unfavorable manner, while the lactic bacteria seem to be the least injurious of all organisms." Hunziker 1920 (12) and Redfield and Stocking 1921 (19) agree that the quality of the cream largely governs the keeping quality of the butter in storage. Bouska and Brown 1921 (2) stated "The deterioration of butter is mainly the result of physical or biochemical causes. An indirect part may be played by microorganisms." Hammer 1921 (10) discussing butter flavors stated, "When butter is held in storage it may go rancid, fishy, metallic, unclean, or any one of a number of other flavors. The temperatures usually used for the storage of butter are so low that the growth of microörganisms is very unlikely, and it is now believed that the deterioration in flavor is due to slow chemical change." Fryhoffer 1922 (5) stated "One thing commonly agreed upon is that acid in cream is essential to the development of fishy flavor." As a result of work carried out at the Iowa State College, Mortensen 1922 (16) stated "Butter made from ripened cream deteriorates faster than either butter made from sweet cream or from sweet cream and starter, but—where low ripening was employed, the ripened butter at the end of a two months cold storage period was about of the same quality as the sweet cream butter and the sweet cream and starter butter." The lack of agreement as to the cause of deterioration of butter in cold storage led to the work herein described.

STATEMENT OF THE PROBLEM

The object of the work carried out was to determine the action of certain bacteria, yeasts and mold on the keeping quality of butter in cold storage. Bacteriological studies were made of the numbers and flora of the raw sweet cream and of the pasteurized sweet cream, and of the butter made therefrom, to seek to determine if any of these were a factor in the keeping quality of the butter in cold storage, and also serve as a check upon the other experiments. To determine the influence of the acidity of the cream the pasteurized sweet cream was divided into several portions and starter added and churning experiments made with cream of different acidities, both with and without the addition of various microörganisms. As the enzymes in the cream were not destroyed at the pasteurization temperature of 145°F. for twenty-five minutes it was sought to determine if the enzymes produced or other disintegration products of the bacteria were a factor in the keeping quality of the butter in cold storage. The starters used were prepared from *Streptococcus lactis* and *Streptococcus paracitrovorus* (8) as it was hoped that the use of cultures, which give a good flavor and aroma, without rapid acid development, would result in the production of butter with exceptional keeping qualities.

METHODS USED

The raw sweet cream delivered at the Iowa State College was pasteurized at 145°F. for twenty-five minutes and treated as follows:

1. Pasteurized sweet cream, acidity 0.14 to 0.21.
2. Pasteurized sweet cream with 10 per cent starter added, not ripened.
3. Pasteurized sweet cream, starter added, ripened to serum x 0.0063.
4. Pasteurized sweet cream, starter added, ripened to an acidity 0.50 to 0.61.

Lots 2, 3, and 4 were divided into two or more portions of 110 to 140 pounds each, and to one or more duplicates before

churning a pure culture of the microörganisms to be tested was added. The material added consisted of 50 to 100 cc. milk culture, seventy-two hours old, plus the scraped off seventy-two hour old growth on two whey agar slants. The incubation was at room temperature. Every effort was made to standardize workmanship in manufacturing the butter. The moisture content was kept as near 16 per cent as practicable and the salt content ranged between 1.5 and 2.1 per cent. Bacteriological studies were made of the cream before churning and of the butter when manufactured and when finally scored. The butter was packed in ten pound tubs and stored for from six to seven months at −6°F. The bacteria used were, in addition to those in the starter, (*S. lactis* and *S. paracitrovorus*).

Bacterium ichthyosmius (7).

Peptonizing coccus. Digested milk in from two to four days, at 20°C. The mold used was *Oidium lactis*, as this is the mold usually found in dairy products.

Owing to the unsatisfactory condition of the classification of dairy yeasts, it is not possible to give definite names to the organisms used, but the following was used as a basis for the series of the experiments.

1. Forming regular white colonies on whey agar.
   - A. Lactose fermenters (9).
   - B. Common white.

Three types of common white yeasts were used in these experiments.

   - A. Large oval yeast, makes milk alkaline in from eighteen to twenty-one days at 20°C.
   - B. Large oval yeast, sweet curdles milk in from eleven to seventeen days at 20°C.
   - C. Large oval yeast, spore-forming, inert in milk.

2. Forming spreading colonies on whey agar.
   - A. Mycoderma. Inert in milk.
   - B. Rapid liquefying yeasts. Liquefy milk in from two to three days at 20°C.

3. Pink yeasts.

Whey agar was used for plating cream to which starter had been added and the butter manufactured therefrom. Whey agar plus 1 cc. 1 per cent tartaric acid was used for estimation of yeasts and molds in cream and butter. Beef infusion agar was used for plating raw sweet cream, pasteurized sweet cream and the butter manufactured therefrom, as it was found to give higher counts than the whey agar since there are types, mainly micrococci, that will not grow on the latter medium. The bacteria were differentiated into various groups by the litmus milk tube method. The acidity of the butter was estimated by dissolving 10 grams in 35 cc. ether and 10 cc. alcohol and, using phenolphthalein as indicator, titrating with tenth-normal sodium hydrate solution. All counts reported are total plate counts.

RESULTS OBTAINED

Data relative to the acidity, the bacterial count and the types of bacteria found in the raw and pasteurized sweet cream are given in table 1. There were 28 lots of cream studied during the period from June to November, 1922. The cream was pasteurized at 145°F. for twenty-five minutes.

In the raw cream the high bacterial counts and the predominance of *S. lactis* will be noticed. When the acidity of the cream reached 0.20 and over, *S. lactis* formed 80 per cent or over of the total flora. There was no definite relationship between the flora of the raw cream and its acidity when the acidity was 0.18 or less, nor between the total bacterial count and the acidity. This is to be expected since the acidity depends on the acid-producing organisms present, and whether their environment is suitable or not, whereas the total count is the sum of several different types. Rennet-acid digesting micrococci and proteolytic types were present to the extent of approximately 1 per cent each in the raw cream; approximately 2 per cent of the flora consisted of *Bact. viscosum*, *Ps. fluor. liquefaciens*, *Eythrobacillus prodigiosus* and members of the coli-aerogenes group. From 50 to 200 *Oidium lactis* was found in each lot of raw cream and from 60 to 3000 yeasts. These yeasts were of the same general types as those used in the inoculation experiments.

It is evident that the cream after pasteurization contains relatively few organisms as compared with the original count, but these counts are higher than are usually considered to be present in pasteurized sweet cream. In 28 experiments the average pasteurization efficiency was 99.55 per cent, which is

TABLE 1

Acidity, bacterial count and types of bacteria found in raw and pasteurized sweet cream

(Summary of results obtained from 28 experiments)

(Raw sweet cream)

	ACIDITY	BACTERIA PER CUBIC CENTIMETER—MILLIONS	PER CENT TYPE					
			A	B	C	D	E	F
Average	0.18	210	71	14	5	14	4	2
Maximum	0.21	388	96	33	22	50	31	17
Minimum	0.14	65	32	0	0	0	0	0

Pasteurized sweet cream

	BACTERIA PER CUBIC CENTIMETER—THOUSANDS	EFFICIENCY OF PASTEURIZATION	PER CENT TYPE				
			C	D	E	F	Y
		per cent					
Average 0.17	957	99.55	34	56	8	2	3
Maximum, 0.20	4,100	99.93	91	94	47	23	11
Minimum 0.13	185	98.54	0	13	0	0	0

A = *S. lactis*. B = *S. lactis var maltigenae*. C = Slow *S. lactis* type. D = Acid-forming, non-coagulating type. E = Alkali-forming type. F = types inert in milk. Y = gram positive micrococci producing yellow pigment. Column Y is included under Column D since they are acid-forming non-coagulating. Column B is included under column A since *S. lactis var maltigenae* belongs to the *S. lactis* group. The organisms included under slow *S. lactis* are so-named for want of definite knowledge of this group. They slowly reduce litmus milk and finally coagulate it after from 4 to 8 days.

slightly lower than the efficiency of 99.93 per cent which was previously reported (6). The difference may be due to the media used; in the previous work the pasteurized sweet cream was plated on whey agar; and this did not permit various micrococci to grow, thus giving lower counts and consequent higher pasteurization efficiency. The typical *S. lactis* type was not found

in the pasteurized cream, and since it was present in the sweet cream butter, it is probable that the cells surviving pasteurization were missed in the dilutions used, or suffered injury during pasteurization and showed an abnormal lag phase, and were included in the slow *S. lactis* group. *S lactis* var. *maltigenae* was not found in the pasteurized cream nor in the butter, so it seems evident that it does not survive a pasteurization temperature of 145°F. for twenty-five minutes. The main surviving types were the slow *S. lactis* and the acid-forming, non-coagulating types. In this latter group were identified *S. paracitrovorus* and lactic acid producing, non-citric acid fermenting Gram positive streptococci, which included a thermophilic type which grew best at 45°C., grew well at 37°C. and poorly at 20°C. There were also found two types of Gram positive micrococci, easily differentiated because one produced yellow pigment and one did not on the media used. The percentage of the yellow pigment-forming type tended to increase with decreasing bacterial counts. They were not found in the raw cream, probably owing to the high dilution used (1 to 1,000,000).

The alkali-forming group, which according to Ayers and his co-workers (1) are primarily soil organisms, largely decreased in number during pasteurization, but increased in relative amount. No member of this group was found in 12 out of the 28 experiments. The group of bacteria inert in litmus milk largely decreased in number during pasteurization, but held their relative percentage of the flora. They were found in 8 out of 28 experiments. The aerobic spore-forming bacteria were not identified in the pasteurized cream, but were found in some of the butter when taken out of cold storage. They were probably missed in the high dilutions used for placing the cream (1 to 10,000). No molds nor yeasts were found in the pasteurized cream. Lund (14) and Thom and Ayers (24) have shown that *Oidium lactis* will not survive heating at 145°F. for ten minutes, and the number of yeasts originally present in the raw cream was too small to draw any conclusion as to their ability to survive pasteurization.

Data relative to the action of *Bact. ichthyosmius* and a peptonizing coccus on the keeping quality of butter cold-stored for six months at −6°F. are given in table 2. Although the butters to which proteolytic bacteria were added decreased somewhat in score, the decrease was not enough to indicate that the addition of the proteolytic bacteria was an important cause of deterioration in butter in cold storage. *Bact. ichthyosmius* was inoculated into cream ripened to 0.50 per cent and into cream to which starter had been added, but not ripened. The results

TABLE 2

Action of proteolytic bacteria on the keeping quality of butter in cold-storage

SCORING	NUMBER OF EXPERIMENTS	ACIDITY OF CREAM	MICROÖRGANISM INOCULATED	SCORE
Initial	2	0.50	A	92.75
Final				91.75
Initial	1	0.50	Check experiment	92.5
Final				92.5
Initial	3	0.22	A	92.18
Final				91.83
Initial	1	0.22	Check experiment	92.0
Final				92.0
Initial	3	0.50	B	93.00
Final				92.17
Initial	1	0.50	Check experiment	92.5
Final				92.5

A = *Bact. ichthyosmius.* B = *Peptonizing coccus* (peptonizing coccus was a Gram positive peptonizing micrococcus isolated from raw sweet cream).

indicate that the acidity of the cream did not favor the production in the butter of undesirable flavors as a result of the action of proteolytic bacteria.

Data relative to the action of various types of yeasts on the keeping quality of butter made from cream ripened to varying acidities and cold stored for six months are given in table 3. Considering that flavor and aroma are qualities in butter that are difficult to give a definite value to when scoring at different intervals, it will be seen that the scores of the butter made from

the uninoculated cream and the inoculated cream agree very well. Although in many experiments there was some decrease in score, a study of the figures show that the yeasts were not a factor in the keeping quality of the butter in cold storage, and that their action was not influenced by the acidity of the cream since the yeasts were inoculated into cream of varying acidities and in several cases the check experiments decreased in score more than the butter made from inoculated cream. Some types of yeasts were more resistant to the adverse conditions than others. *Pink yeast* and *Mycoderma* did not survive while 80 to 98 per cent of the lactose fermenting types (*T. cremoris* and *T. sphaerica*) and *Common White* types died off in cold storage. The most resistant type was the Digesting yeast of which an average of 43 per cent survived. From 10 to 25 per cent of the yeast count per cubic centimeter in cream was found per cubic centimeter in butter, except with the *pink yeast* which apparently found conditions adverse from the start.

Date relative to the action of (a) *Oidium lactis* and yeasts and (b) *Oidium lactis* alone, inoculated into cream at varying acidities, in relation to the keeping quality of butter in cold storage are given in table 4.

Although there was a decrease in score of the butter, it is evident that the combination of yeasts and *Oidium lactis*, or *Oidium lactis* alone did not cause deterioration in cold storage, and that the acidity of the ripened cream did not favor deterioration by these microörganisms. These results confirm those of Rogers 1909 (21) who was unable to produce fishy butter by the inoculation of *Oidium lactis* into cream, although O'Callaghan 1907 (17) had claimed that *Oidium lactis* produces fishiness in butter. The fact that no *Oidium lactis* survived in the cold storage butter shows that it was in an unfavorable environment.

Data relating to the bacterial count, flora and score of sweet cream are given in table 5. The data shows that organisms of the various groups can survive in butter that has been cold stored six months at −6°F. The acid-forming, non-coagulating type formed 70 per cent of the flora at the initial scoring and 80 per cent at the final scoring. It is evident that *S. paracitrovorus*,

TABLE 3

Action of yeasts on the keeping quality of butter in cold-storage

SCORING	NUMBER OF EXPERIMENTS	ACIDITY OF CREAM	MICROÖRGANISM INOCULATED	NUMBER IN CREAM	NUMBER IN BUTTER	SCORE	INCREASE OR DECREASE IN SCORE
Initial*	6	0.27	Common white yeast	10,600	930	92.83	
Final					33	92.25	−0.58
Initial	3	0.28	Check experiments			93.17	
Final						92.83	−0.34
Initial	6	0.44	Common white yeast	28,800	6,100	91.79	
Final					450	91.21	−0.58
Initial	5†	0.44	Check experiments			92.10	
Final						90.90	−1.20
Initial	2‡	0.56	Common white yeast	34,400	6,000	91.00	
Final					110	91.50	+0.50
Initial	6	0.50	Lactose-fermenting yeasts	35,900	4,020	92.00	
Final					840	91.75	−0.25
Initial	4	0.51	Check experiments			92.12	
Final						91.64	−0.48
Initial	5	0.30	Digesting yeast	33,200	8,540	91.70	
Final					3,680	91.90	+0.20
Initial	2	0.31	Check experiments			92.00	
Final						91.50	−0.50

Initial	4	0.24	Pink yeast	32,750	1,200	92.12	
Final					None	91.87	−0.35
Initial	2	0.24	Check experiments			92.00	
Final						92.00	±0.0
Initial	5	0.31	Mycoderma	7,260	860	92.50	
Final					None	92.80	+0.30
Initial	2	0.29	Check experiments			92.50	
Final						92.25	−0.25

* All figures given are the average figures for the experiments carried out.

‡ These experiments were duplicates of experiments averaged in 5†. Three types of common white yeast were used in the experiments, but as the results secured with them were essentially alike, they are included under one heading in above table.

TABLE 4

Action of Oidium lactis and yeasts and Oidium lactis alone on the keeping quality of butter in cold storage

SCORING	NUMBER OF EXPERIMENTS	ACIDITY OF CREAM	MICROÖRGANISM USED	NUMBER IN CREAM	NUMBER IN BUTTER	SCORE	INCREASE OR DECREASE IN SCORE
Initial ..	7	0.48	M plus L	33,360 Y 1.710 M	8.100 Y 234 M	92.70	
Final					820 Y	90.93	−1.77
Initial ..	7	0.48	Check experiments			92.57	
Final						91.00	−1.57
Initial ..	3	0.44	M	2.730 M	1.470 M	92.33	
Final					None	92.18	−0.15
Initial ..	3	0.44	Check experiments			91.83	
Final						91.69	−0.14
Initial ..	2	0.57	M	3.150 M	1.700 M	92.00	
Final					None	90.50	−1.50
Initial ..	2	0.57	Check experiments			92.00	
Final ...						90.75	−1.25

M = *Oidium lactis*. Y = Yeasts.

TABLE 5

Bacterial count, flora and score of sweet cream butter at initial and final scorings

SCORING	BACTERIA PER CUBIC CENTIMETER—THOUSANDS	PER CENT TYPE					
		S. lactis	Slow S. lactis	Non-coagulating acid forming	Alkali forming	Inert	Peptonizing
Initial*.....	167	0	20	70	6	4	0
Final*.....	141	6	8	80	2	1	3

	ACIDITY OF CREAM	BACTERIA PER CUBIC CENTIMETER IN BUTTER—THOUSANDS		ACIDITY OF BUTTER		SCORE	
		Initial	Final	Initial	Final	Initial	Final
Average*.....	0.18	167	141	1.08	1.17	91.71	91.76
Maximum.....	0.21	630	600	1.40	1.50	93.0	33.0
Minimum.....	0.14	54	30	0.90	1.00	90.5	90.0

* Average of 19 experiments.

lactic-acid producing, non-citric acid fermenting streptococci and various types of micrococci can resist pasteurization and cold storage conditions, and thus show themselves to be very resistant to unfavorable conditions. *S. lactis* was not found in the butter when manufactured, but was found after cold storage. The butter manufactured from the sweet cream retained 5 to 30 per cent of the bacteria per cubic centimeter of the cream; usually between 20 to 30 per cent was found; and 35 to 100 per cent of the bacteria per cubic centimeter originally in the butter was found after the cold storage period. It is evident from the scores that the butter showed excellent keeping quality, having a slightly higher average score when it came out of cold storage than it had when it went in and that the flora of the pasteurized sweet cream did not cause deterioration in cold storage.

Data relative to the bacterial count per cubic centimeter of the cream, buttermilk and butter; the acidity of the cream and butter, and the score of the butter at the initial and final scorings are given in table 6. The number of bacteria per cubic centimeter as determined by the plate method, in the cream to which starter had been added, had no definite relation to the acidity of the cream. This is to be expected since the production of acidity is a function: (a) of the ratio of *S. lactis* to *S. paracitrovorus*, (b) the rate of acid production of the *S. lactis* inoculated. The buttermilk, except in a few instances, showed a higher bacterial count per cubic centimeter than the cream did, but no definite relationship existed. The following causes are suggested as to why a higher count should be obtained per cubic centimeter in the butter-milk than in the cream; (a) removal of the butterfat containing comparatively few bacteria, (b) breaking up of bacterial clumps by agitation during churning. The flora of the cream to which starter had been added was found to consist of *S. lactis* and *S. paracitrovorus*, the *S. lactis* forming 90 to 100 per cent of the flora. Other organisms must have been present, but were probably missed owing to the high dilution necessary for plating (1 to 1,000,000).

The butter made from cream to which starter had been added and (a) not ripened and (b) ripened to varying acidities, retained

TABLE 6

Bacteriological count of the cream, buttermilk and butter, acidity of the cream and butter and score of butter at initial and final scorings

ACIDITY OF CREAM	BACTERIAL COUNT				ACIDITY OF BUTTER		SCORE	
	Cream—millions	Butter milk—millions	Butter					
			Initial—thousands	Final—thousands	Initial	Final	Initial	Final
Sweet cream plus 10 per cent starter (8 experiments)								
Average 0.28...	278	336	4,100	95	1.30	1.32	92.56	92.12
Maximum, 0.35...	530	610	8,500	285	1.50	1.50	94.0	93.0
Minimum 0.22...	77	90	650	3	1.20	1.20	91.0	90.0
Sweet cream plus 10 per cent starter plus added microörganisms (23 experiments)								
Average 0.27...	256	302	3,250	91	1.28	1.32	91.94	91.84
Maximum, 0.35...	510	600	7,800	460	1.45	1.50	93.5	94.0
Minimum 0.22...	70	78	600	3	1.20	1.15	91.0	90.0
Sweet cream ripened to serum × 0.0063 (22 experiments)								
Average, 0.44...	196	211	2,813	69	1.55	1.68	92.34	91.00
Maximum, 0.46...	510	540	12,400	336	2.00	2.20	93.5	92.5
Minimum 0.42...	67	73	520	1	1.35	1.50	91.5	88.0
Sweet cream ripened to serum × 0.0063 plus added microörganisms (17 experiments)								
Average, 0.44...	105	127	1,170	28	1.64	1.75	92.03	91.41
Maximum, 0.46...	160	205	1,850	86	2.20	2.20	93.0	93.5
Minimum 0.42...	63	78	440	2	1.40	1.40	91.0	88.0
Sweet cream ripened to from 0.50 to 0.61 (7 experiments)								
Average, 0.55...	232	282	2,650	52	1.96	1.96	92.21	90.57
Maximum, 0.61...	550	730	5,300	270	2.20	2.40	92.5	91.5
Minimum 0.50...	123	144	960	3	1.75	1.75	91.5	90.0
Sweet cream ripened to from 0.50 to 0.61 plus added microörganisms (16 experiments)								
Average, 0.53...	319	391	3,305	78	1.81	1.96	92.09	91.62
Maximum, 0.61...	800	960	7,300	305	2.35	2.35	93.0	93.0
Minimum 0.50...	74	87	630	2	1.45	1.50	90.5	90.0

per cubic centimeter from 0.5 to 2 per cent of the bacteria per cubic centimeter of the cream, generally about 1 per cent. The flora of the butter was found to consist of *S. lactis* and *S. paracitrovorus*, the *S. lactis* forming 70 to 100 per cent of the flora, usually over 90 per cent. The dilution used for plating (1 to 10,000) probably accounts for other organisms not being found. The average dying off of bacteria during the six months cold storage at −6°F. was over 98 per cent. This, considering the larger initial bacterial count of the butter, is in marked contradistinction to the results obtained with the sweet cream butter. When taken out of cold storage, the sweet cream butter often had a higher bacterial count per cubic centimeter than the butter made from cream to which starter had been added. This seems to show that the normal flora of pasteurized cream find an acid environment unfavorable; also the utilization of the lactose by *S. lactis* and *S. paracitrovorus* may be a factor. The flora of the butter when taken out of cold storage was found to consist chiefly of *S. lactis* and the acid-forming non-coagulating types, and usually contained from 100 to 2000 yellow pigment forming micrococci per cubic centimeter. *S. paracitrovorus* was usually present. The per cent of *S. lactis* varied from 0 to 100 per cent, but was usually present in some amount. The acid-forming non-coagulating type varied from 0 to 100 per cent; usually the lower the bacterial count of the butter the greater the percentage of this type.

The butter made from sweet cream to which starter had been added, but not ripened, had a higher initial score than the sweet cream butter. The score decreased on the average 0.44 points whereas the sweet cream butter increased its score on the average 0.05 points, yet the final score was higher by 0.36 points than the sweet cream butter. This shows that this method of butter manufacture is practicable, and it has the advantage that the butter has a flavor which makes it more desirable.

The average score of the butter made from the uninoculated cream, ripened to serum x 0.0063 was 92.34 points. This type of butter lost 1.34 points in cold storage, thus having a lower average score by 0.76 points than the sweet cream butter, but

the average score of 91.0 points after six months cold storage shows better keeping quality than is usually credited to this type of butter.

The average score of the butter made from the uninoculated cream ripened to 0.50 to 0.61 was 92.21 points. This type of butter lost 1.64 points during six months cold storage, and the corresponding decrease for the butter made from inoculated ripened cream was 0.47 points. The final average score of 90.57 points for the uninoculated butter and 91.62 points for the inoculated butter shows better keeping quality than is usually credited to this type of butter, and also that the addition of the microörganisms did not cause deterioration. It is also evident that while lactic acid may be a factor in deterioration it is not a direct cause of it.

That lactic acid may aid as a factor in deterioration is shown by the fact that several churnings decreased from a 92 to an 88 point score, while the check churning made from the sweet cream without the addition of starter retained its score or only slightly decreased in score. It is this fact that has led to the association of acidity of cream with deterioration of butter in cold storage, and the increasing demand for sweet cream butter for storage purposes. A proof that *S. lactis* and *S paracitrovorus* are not a direct cause of deterioration is shown by the keeping quality of the butter made from cream to which starter had been added but not ripened.

The acidity of the butter increased as the acidity of the cream increased, but the individual range is so wide, that it seems that the acidity of the butter is not in proportion to the acidity of the cream, but is influenced by other factors, such as the treatment during manufacture.

CONCLUSIONS

1. There was an average pasteurization efficiency of 99.55 per cent when sweet cream was pasteurized at 145°F. for twenty-five minutes.

2. The bacterial count of the ripened cream had little or no relation to the acidity of the cream.

3. The bacterial count per cubic centimeter of the butter made from ripened cream had no definite relation to the bacterial count per cubic centimeter of the ripened cream.

4. The butter made from ripened cream retained per cubic centimeter from 0.5 to 2 per cent of the bacteria per cubic centimeter of the ripened cream, generally about 1 per cent.

5. The butter made from pasteurized sweet cream retained per cubic centimeter from 5 to 30 per cent of the bacteria per cubic centimeter of the pasteurized sweet cream, generally between 20 to 30 per cent.

6. From 95 to 99 per cent of the bacteria of the ripened cream died off during six months cold storage, generally from 98 to 99 per cent.

7. The average decrease in the bacteria in the butter made from pasteurized sweet cream during six months cold storage was approximately 20 per cent, the maximum decrease was 65 per cent, the bacterial count per cubic centimeter of some butters did not show any decrease.

8. Resistant strains of *S. lactis*, slow *S. lactis* type, *S. paracitrovorus*, lactic acid forming, non-coagulating, non-citric acid fermenting streptococci, various types of micrococci, inert types, alkali-forming types and proteolytic types lived over in the butter, cold-stored for six months.

9. Taking the acidity of the butter as a criterion, there was little or no detectable hydrolysis of the butterfat during six months cold storage.

10. The acidity of the butter increased as the acidity of the cream increased, but there was no definite relation between the acidity of the butter and the acidity of the cream.

11. Proteolytic bacteria, various types of yeasts found in dairy products, and *Oidium lactis* were added to ripened and unripened cream containing starter before churning and were found not to be a significant factor in the deterioration of butter in cold storage for six months at −6°F.

12. There was no evidence that the enzymes produced during the growth of the microörganisms or the disintegration products produced on the death of the microörganisms affected the keeping quality of the butter in cold storage.

13. Sweet cream butter was found to keep well in cold storage and for the most part to retain its original score. One hundred per cent of the lots of butter scored 90 and over both when put into and taken out of cold storage.

14. Butter made from sweet cream plus 10 per cent starter, unripened, was found to have good keeping quality and to have a slightly higher average score when taken out of cold storage than the churnings made from pasteurized sweet cream. One hundred per cent of the butters scored 90 and over, both when put into and taken out of cold storage.

15. Butter made from sweet cream ripened with a mixture of *S. lactis* and *S. paracitrovorus* showed good keeping quality in cold storage, but marked deterioration of occasional churnings occurred. One hundred per cent of the butters scored 90 and over when put into cold storage, and 83 per cent of these butters scored 90 and over when taken out of cold storage.

16. Where deterioration of butter occurs in cold storage it is not due to the normal flora of pasteurized cream, nor to *S. lactis* or *S. paracitrovorus*, nor to the lactic acid formed during the ripening of cream by a starter.

17. The occurrence of erratic decreases in score of butter made from ripened cream, which rarely occurs when the cream is not ripened, suggests that the deterioration of butter made from ripened cream is due to some as yet undetermined cause, which may be aided in its action by the lactic acid produced during the ripening of the cream.

18. The quality of the cream when delivered at the creamery is probably the main factor that determines the keeping quality of butter in cold storage.

I desire to return thanks to Professor M. Mortensen, for providing means for carrying out this work; to Doctor B. W. Hammer, for his helpful advice and criticism at all stages of the work and to the following who acted as judges in scoring the butter: Mr. Howard D. Reynolds, Mason City, Iowa; Professor A. W. Rudnick, Extension Department, Iowa State College, and Mr. J. J. Brunner, Extension Department, Iowa State College.

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A STUDY OF THE RELATION OF THE COMPOSITION OF THE MIX TO THE QUALITY OF THE FINISHED ICE CREAM[1]

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This investigation was undertaken to study the relation of the percentage of butterfat, milk solids not fat, and total milk solids in the mix to the quality of the frozen ice cream.

Several series of mixes were prepared, varying in composition as shown in table 1.

The materials used in the preparation of the mixes were cream containing forty per cent butterfat, skimmed milk, superheated condensed skimmed milk, water, cane sugar, gelatin, and vanilla extract. The same amounts of sugar (12 per cent), gelatin (0.5 per cent), and vanilla extract (0.5 per cent) were used in all mixes, the other materials were varied to give the desired composition.

The cream, skimmed milk, and condensed milk were pasteurized.[2]

The mixes were frozen in an ordinary brine freezer of fifty quarts capacity. The temperature of the brine ranged from 4° to 12°F. and the time of freezing from twelve to twenty minutes. The brine was pumped through the freezer until the temperature of the mix reached 26° to 27°F. or until the mixture began to freeze, then shut off. The ice cream was allowed to whip until the maximum swell was secured, as determined with a Mojonnier overrun tester.

[1] This article is based on a thesis presented to the Faculty of the Graduate School of the University of Illinois by A. S. Ambrose in partial fulfillment of the requirements for the degree of Master of Science in Dairy Husbandry.

[2] The mixes were not homogenized or viscolized. A separate study of these processes and their influence upon the composition of ice cream is now in progess.

Samples of the finished ice cream were taken in each case, when the ice cream was half drawn from the freezer. These were drawn into small cartons, placed in a hardening room and held until time of examination. The first sample of each lot was examined between two days and one week after freezing, and the succeeding samples at intervals of seven to ten days apart. A number of the samples were held as long as forty-six days.

TABLE 1

Composition of mixes

MIX NUMBER	PERCENTAGE BUTTERFAT	PERCENTAGE M.S.N.F.	PERCENTAGE CANE SUGAR	PERCENTAGE GELATIN	PERCENTAGE TOTAL SOLIDS
1	8	6	12	0.5	26.5
2	8	10	12	0.5	30.5
3	8	12	12	0.5	32.5
4	8	14	12	0.5	34.5
5	8	18	12	0.5	38.5
6	10	6	12	0.5	28.5
7	10	10	12	0.5	32.5
8	10	12	12	0.5	34.5
9	10	14	12	0.5	36.5
10	10	18	12	0.5	40.5
11	12	6	12	0.5	30.5
12	12	10	12	0.5	34.5
13	12	12	12	0.5	36.5
14	12	14	12	0.5	38.5
15	12	18	12	0.5	42.5
16	14	6	12	0.5	32.5
17	14	10	12	0.5	36.5
18	14	12	12	0.5	38.5
19	14	14	12	0.5	40.5
20	14	18	12	0.5	44.5

In some cases as many as four mixes of one composition were prepared and frozen at different times, in other cases only one mix of a certain composition was prepared and frozen. Fifty-three separate mixes, a total of four hundred and fifty gallons of ice cream, were prepared and frozen.

BASIS OF COMPARISON

It was necessary to formulate a definition of a good commercial ice cream in order to have a uniform basis of comparison. A

definition acceptable to all is manifestly impossible because of individual preferences. However, certain general qualities seemed essential. These characteristic qualities may be considered under the headings of texture, resistance, body, flavor, and stability.

Flavor refers to the taste imparted by the ingredients; for example, the flavor of the condensed milk used, or the taste which may develop during storage, such as old or stale flavors, condensed milk flavor, or "lactose" flavor. The term "lactose" is used to designate a mildly sweet, somewhat saline flavor that frequently occurs in ice cream which contains a comparatively high milk sugar concentration.

Texture refers to the size, shape and arrangement of the particles or the structure of the ice cream. An ideal texture is one which is perfectly smooth or entirely free from all graininess.

Resistance is the property of the ice cream to resist melting when placed in the mouth. An ice cream is undesirable when it melts down like snow, so also is one which is so resistant as to be soggy. The degree of resistance is relative and can best be described as too little, good, or too much.

Body refers to the total organized substance or the mass of ice cream as a whole. It is dependent upon the texture and resistance. It may be described as light, good, heavy, or soggy.

Stability is the property of the ice cream to retain the desirable qualities. A freshly frozen product may seem to possess all the desirable qualities and yet serious defects may develop in flavor, body, or texture after it has been held in storage, or in dealers' cabinets for a few days.

"Sandiness" refers to a condition which sometimes occurs in ice cream, and which is generally conceded to be caused by crystallization of milk sugar.[3] Such ice cream contains many particles resembling fine sand which dissolve in the mouth with difficulty. "Sandy" ice cream must not be confused with "grainy" ice cream. The term "grainy" refers to a condition

[3] Sandy crystals in ice cream: Their separation and identification, Harper F. Zoller and Owen E. Williams, Journal of Agricultural Research, vol. xxi, no. 10, August 15, 1921.

caused by the crystallization of comparatively large particles of ice which dissolve in the mouth readily.

The terms used in judging the ice creams were as follows:

TEXTURE	RESISTANCE	BODY	FLAVOR
Very smooth (velvety)	Too much	Soggy	Condensed milk
Smooth	Good	Heavy	Lactose
Coarse	Lacking	Good	Old or stale
Very coarse		Light	

The samples were examined by four judges and a summary of the criticisms of 150 samples is presented in the accompanying tables.

RELATION OF THE PERCENTAGE OF TOTAL MILK SOLIDS TO TEXTURE, RESISTANCE, BODY, AND FLAVOR OF ICE CREAM

Table 2 contains the criticisms of the ice creams with the samples arranged according to the total milk solids content.

It is evident from this table that the ice creams which contained a low total milk solids content (14.0 to 20.0 per cent) were unsatisfactory in every way as they were more or less coarse in texture, lacking in resistance, and light in body. The ice creams with a high total milk solids content (28.0 to 32.0 per cent) were also unsatisfactory in that they were entirely too resistant and had heavy or soggy body.

The quality of the ice creams which had the same total milk solids content was not the same, for example, series 8, 9, and 10 all contained 22 per cent total milk solids yet the texture varied from coarse to smooth, the resistance from lacking to good, and the body from light to good. Similarly, there were differences in series 11, 12, and 13 with 24 per cent total milk solids, and in the series 14, 15, and 16 with 26 per cent total milk solids. There are likewise variations in series with high total milk solids, and in series with low total milk solids, although the variation in quality within each of these series is not as marked as in the series with a medium total milk solids content.

The data indicate that the quality of ice cream is dependent upon the kind of the milk solids more than upon the percentage of total milk solids, although a good quality of ice cream cannot be had with either a very low or a very high total milk solids content.

TABLE 2

Relation of percentage of total milk solids to texture, resistance, and body of ice cream

SERIES	PER CENT FAT	PER CENT M.S.N.F.	PER CENT T.M.S.	TEXTURE	RESISTANCE	BODY
1	8	6	14.0	Very coarse	Lacking	Light
2	10	6	16.0	Very coarse	Lacking	Light
3	8	10	18.0	Coarse	Lacking	Light
	12	6	18.0	Very coarse	Lacking	Light
4	10	10	20.0	Coarse	Lacking	Light+
	14	6	20.0	Very coarse	Lacking	Light
	8	12	20.0	Coarse	Lacking+	Light+
5	8	14	22.0	Smooth	Good	Good
	12	10	22.0	Coarse	Lacking	Light+
	10	12	22.0	Coarse+	Good	Good
6	10	14	24.0	Smooth	Good	Good+
	14	10	24.0	Coarse	Good−	Good−
	12	12	24.0	Smooth+	Good	Good
7	8	18	26.0	Very smooth	Good+	Heavy
	12	14	26.0	Smooth+	Good+	Heavy−
	14	12	26.0	Very smooth	Good+	Heavy
8	10	18	28.0	Very smooth	Too much	Heavy+
	14	14	28.0	Very smooth	Too much	Heavy−
9	12	18	30.0	Very smooth	Too much	Soggy
10	14	18	32.0	Very smooth	Too much	Soggy

RELATION OF THE PERCENTAGE OF MILK SOLIDS NOT FAT TO TEXTURE, RESISTANCE, BODY, AND FLAVOR OF ICE CREAM

A study of table 3 shows that the ice creams which contained 6 per cent milk solids not fat were very coarse in texture, lacking in resistance, and light and snowy in body in every instance.

They were also partially churned. The small percentage of milk solids not fat, seemingly, did not offer sufficient internal resistance to prevent churning during the freezing process.

The ice creams which contained 18 per cent milk solids not fat had velvety texture, very heavy or soggy body, and were entirely

TABLE 3

Relation of the percentage of milk solids not fat to texture, resistance, body, and flavor of ice cream

SERIES	PER CENT M.S.N.F.	PER CENT B.F.	TEXTURE	RESISTANCE	BODY
A	6	8	Very coarse	Lacking	Light
	6	10	Very coarse	Lacking	Light
	6	12	Very coarse	Lacking	Light
	6	14	Very coarse	Lacking	Light
B	10	8	Coarse	Lacking	Light
	10	10	Coarse	Lacking	Light
	10	12	Coarse	Lacking	Light+
	10	14	Coarse	Good−	Good−
C	12	8	Coarse	Lacking	Light+
	12	10	Coarse+	Good	Good
	12	12	Smooth	Good	Good
	12	14	Very smooth	Good+	Heavy
D	14	8	Smooth	Good	Good
	14	10	Smooth	Good	Good+
	14	12	Smooth +	Good+	Heavy−
	14	14	Very smooth	Too much	Heavy−
E	18	8	Very smooth	Good	Heavy
	18	10	Very smooth	Too much	Heavy+
	18	12	Very smooth	Too much	Soggy
	18	14	Very smooth	Too much	Soggy

too resistant. It would seem, that as far as texture, resistance, and body are concerned 6 per cent milk solids not fat produce a quality of ice cream of one extreme and 18 per cent the other extreme. Between these extremes there is a more or less gradual change in these qualities as the percentage of milk solids not fat increases. The texture changes from coarse to very smooth or velvety, the body from light to heavy, and the resistance becomes

greater. This tendency is apparent in each series although the butterfat content remained constant.

The data indicate that a certain proportion of milk solids not fat is necessary to produce smooth texture, good resistance, and desirable body regardless of the percentage of butterfat present. Added milk solids not fat beyond this amount and up to a certain point bring about an increased smoothness in texture, greater resistance, and heavier body. However, there is a limit beyond which further increases in milk solids not fat are of little or no value in this respect.

The flavor of all the ice creams was very good when first frozen. Those which contained 12, 14, and 18 per cent milk solids not fat frequently developed a condensed milk or "lactose" flavor in from two to three weeks after they had been placed in storage. These flavors rarely developed in the ice creams which contained less than 12 per cent milk solids not fat.

Sandiness often developed in the ice creams which contained 14 to 18 per cent milk solids not fat, while it was evident in only two cases in the ice creams which contained less than 14 per cent. This condition usually did not appear until after the ice cream had been in storage for about two or three weeks and was more often apparent after three weeks.

RELATION OF THE PERCENTAGE OF BUTTERFAT TO TEXTURE, RESISTANCE, BODY, AND FLAVOR OF ICE CREAM

Table 4 contains the same data arranged in series with variations in the percentages of butterfat.

It is evident that in some series increased percentages of butterfat had no effect upon the quality of the ice creams, while in other series as little as 2 per cent increase brought about a change. The criticisms of texture of the ice creams in series A, B, and E were the same within each series although the percentage of butterfat ranged from 8 to 14 per cent. However, there were variations in series C and D within each series. The 12 per cent milk solids not fat ice creams (series C) varied from coarse to very smooth, and 14 per cent milk solids not fat ice creams (series D)

varied from smooth to very smooth. The criticisms of resistance and body show quite similar variations. A probable explanation for this is as follows:

As stated under the discussion of the relation of milk solids not fat, a certain proportion of milk solids not fat seems necessary to produce a good quality of ice cream. With less than this proportion any increase in the amount of butterfat, from 8 to 14 per

TABLE 4

Relation of the percentage of butterfat to texture, resistance, body, and flavor of ice cream

SERIES	PER CENT FAT	PER CENT M.S.N.F.	TEXTURE	RESISTANCE	BODY
A	8	6	Very coarse	Lacking	Light
	8	10	Coarse	Lacking	Light
	8	12	Coarse	Lacking+	Light+
	8	14	Smooth	Good	Good
	8	18	Very smooth	Good+	Heavy
B	10	6	Very coarse	Lacking	Light
	10	10	Coarse	Lacking	Light+
	10	12	Coarse+	Good	Good
	10	14	Smooth	Good	Good+
	10	18	Very smooth	Too much	Heavy
C	12	6	Very coarse	Lacking	Light
	12	10	Coarse	Lacking	Light+
	12	12	Smooth	Good	Good
	12	14	Smooth+	Good+	Heavy−
	12	18	Very smooth	Too much	Soggy
D	14	6	Very coarse	Lacking	Light
	14	10	Coarse	Good−	Good−
	14	12	Very smooth	Good+	Heavy
	14	14	Very smooth	Too much	Heavy−
	14	18	Very smooth	Too much	Soggy

cent, has little or no effect upon the quality of ice cream. When the proportion of milk solids not fat is sufficient, an increased percentage of butterfat acts very much the same as increased milk solids not fat, that is, produces smoother texture, greater resistance, and more desirable body. In other words, the two have a complimentary value within certain limits. As in the case

of milk solids not fat, there is an upper limit beyond which an increase in the butterfat content, seemingly, does not improve the quality of ice cream.

It is evident from these data that there is a lower and an upper limit wherein the butterfat influences the quality of ice cream. The lower as well as the upper limit is dependent upon the percentage of milk solids not fat. Between these limits a difference in quality is evident with a smaller increase in the percentage of butterfat when the milk solids not fat content is increased.

In addition to the effect upon texture, resistance, and body the butterfat influences the flavor of ice cream. Here also, the milk solids not fat have an influence. With the low milk solids not fat content (6 per cent) the increase in fat content from 8 to 14 per cent, did not improve the flavor. In all other cases increased percentages of butterfat produced ice cream with richer flavor. The ice creams which contained 14 per cent butterfat were extremely rich.

CONCLUSIONS

The quality of ice cream with respect to texture, body, and resistance is dependent more upon the kind of milk solids than upon the total milk solids. The milk solids not fat are more essential than the butterfat in this respect.

In general a good commercial ice cream can be made with fr m 10 to 12 per cent milk solids not fat and 8 to 14 per cent butterfat. An excellent quality of ice cream was obtained with 12 per cent butterfat and 12 per cent milk solids not fat.

A high percentage of milk solids not fat (14 to 18 per cent) is conducive to a condensed milk or "lactose" flavor and also to a "sandy" condition where condensed milk is used to supply the milk solids not fat in ice cream.

A high percentage of butterfat produces a richer flavored ice cream.

A GREENISH-BLACK DISCOLORATION OF CHOCOLATE ICE CREAM

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An ice cream manufacturer in New York, during the winter of 1922–1923, was troubled with a greenish-black discoloration that appeared sporadically in his chocolate ice cream. The discoloration was described by the manufacturer as spots slightly greenish in color. These spots developed in five or six cans out of fifty and were not confined to any special ice cream mix. The time required for these spots to appear varied from one to ten days. They usually developed in the hardening room, although in other cases, they developed only after the ice cream was put in the retailer's cabinet. No excessive numbers of bacteria were found by the manufacturer, and no molds were in evidence. Tin and copper were absent in these spots, and a trace of iron was present in quantities comparable to that found in the normal colored chocolate ice cream.

THE CHEMISTRY OF THE DISCOLORATION

Examination of a 5-gallon can of this ice cream sent to this Station showed a ring of greenish-black color in the chocolate around the extreme outside of the ice cream next to the can. By removing large pieces of ice cream from the can it became evident that the greenish-black spots on the ice cream matched identically in pattern the rust spots on the can. No spots could be found where the can was well tinned or in the ice cream at any other place than where it was exposed to rusty places. The flavor of these spots was extremely fishy. Since Rogers, Berg, Potteiger and Davis[1] have found that metallic salts,

[1] L. H. Rogers, W. N. Berg, C. R. Potteiger, B. J. Davis. Factors Influencing the Flavor of Storage Butter. U. S. Dept. of Agric., B. A. I. Bul. 162. 1913.

especially iron, accelerate the production of fishy flavor in butter, the evidence seemed to indicate that iron was one of the essentials for the production of the greenish-black discoloration.

Some of the ice cream was repacked into a new container and on the surface of the ice cream were placed strips of tinned iron with and without rust spots. Some of the strips were dipped in a concentrated sodium chloride solution to hasten the formation of rust. Part of the ice cream so treated was held continuously at −10° to 0°F. and part of it was softened daily at a warm temperature. Within twenty-four hours the discoloration appeared on the chocolate ice cream exposed to rusty iron dipped in salt brine. In four or five days it appeared by the strip of tinned iron which had exposed rust spots, but it required about two weeks for a trace of the color to become noticeable by exposed iron well scoured and free from rust. The alternate softening and hardening hastened the production of the color and increased its intensity.

To obtain more conclusive evidence of the part played by iron in the production of this color a few drops of a 10 per cent solution of chemically pure ferric chloride were added to a limited area of frozen chocolate ice cream and a greenish-yellow discoloration appeared instantly which changed in a few minutes to greenish-black.

This discoloration appeared in no other ice cream than chocolate. Hence, the chemical with which the iron was combined to produce the greenish-black color must be contained in cocoa. Analyses given in chemical books treating in plant products, as well as those obtained through the courtesy of two chocolate and cocoa manufacturers, gave two classes of compounds whose properties are such that they may have been responsible for this color, namely, the proteins and the tannins. Cocoa contains 10 to 20 per cent protein and 2 to 5 per cent tannin. The ferric salts of tannins are blue, green, black or any combination of these three colors. They have been used as the basis of several inks.

When a few drops of a 10 per cent solution of ferric chloride were added to 10 cc. of a 5 per cent solution of cocoa the solution

became intensely black. The cocoa used was obtained from the manufacturer in whose ice cream the greenish-black color appeared. The solution of cocoa was made in boiling water in order to obtain a high degree of solution.[2] When the black cocoa solution was filtered most of the color filtered out, but the filtrate was also very black. To the clear brown filtrate from a 5 per cent cocoa solution a few drops of ferric chloride were added and a heavy bluish black precipitate appeared. When this was filtered the filtrate was also black. The compounds in the cocoa that combined with the iron were therefore soluble in water while the greenish-black color was due to both soluble and insoluble compounds.

American standard horse hide powder was prepared according to the method described in the methods of analyses as published by the American Association of Agricultural Chemists. The filtrate of a 5 per cent cocoa solution was treated with this hide powder as if a tannin determination of the filtrate was being made. The hide powder removed the tannin from solution and when ferric chloride was then added to the filtrate no greenish-black color developed.

From the work with cocoa filtrates it became evident that the acidity or alkalinity of the solution as well as the degree of dilution changes the character of the color developed and may entirely prevent its appearance. To learn if the hide powder had interfered in any other way with the development of the color, an equal quantity of cocoa filtrate was added to that treated with hide powder and ferric chloride then produced the characteristic color. The production of a greenish-black color or precipitate with iron and the combination with hide are two of the distinguishing characteristics of tannins.

There are two classes of compounds in cocoa that contain nitrogen; the proteins and theobromine. For this reason the total nitrogen content of the cocoa as determined was not calculated as protein due to the error that would be introduced by the theobromine. The cocoa contained 3.44 per cent nitrogen.

[2] The mixture of cocoa with boiling water is not a true solution, but the various constituents exist in true solutions, colloids, and suspensions.

More than half of the nitrogen-containing material was not dissolved in boiling water, but filtered out. One hundred cc. of a 5 per cent cocoa solution were filtered, and 20 cc. of the filtrate were found to contain 0.0136 gm. nitrogen. In other words, 1.36 per cent nitrogen passed through the filter paper. Ferric chloride was added to some of the cocoa solution and the filtrate, representing 1 gram of cocoa, was found to contain 0.0109 gram nitrogen, which represents 1.09 per cent nitrogen in the cocoa that passed into the filtrate. This difference of 0.27 per cent nitrogen represents some protein that was precipitated by the iron, and protein occluded by the ferric tannate precipitate. The theobromine being soluble in water in such small quantities could not account for this reduction in filterable nitrogen resulting from the addition of ferric chloride to the cocoa solution if it was precipitated by ferric salts.

COCOAS VARY IN PRODUCING DISCOLORATION

The conditions favorable to the production of this discoloration of chocolate ice cream are prevalent in the ice cream business so that it is surprising that this difficulty has not been more generally encountered. To obtain information on this point the ability of various grades of cocoa to produce this discoloration was determined.

Through the courtesy of a cocoa manufacturer four different grades of cocoa were obtained. One of them was a high grade "Dutch Process" cocoa and the other three represented their highest, lowest, and medium grade cocoas. Two samples of cocoa were purchased at a grocery store in Geneva; one retailing for 35 cents per pound, and the other for 10 cents. The ice cream manufacturer having difficulty with the greenish-black color supplied us with samples of two different cocoas he was using. The ability of each of these eight samples to produce the discoloration in chocolate ice cream was determined by the addition of a few drops of 10 per cent solution of ferric chloride to 10 cc. of a 5 per cent solution of cocoa. It was found that only three out of the eight cocoas tried could produce the greenish-

black color. They were: the "Dutch Process" cocoa, the cocoa retailing at 35 cents per pound which was the product of the company manufacturing "Dutch Process" cocoa, and one of the samples submitted by the ice cream manufacturer. All of these cocoas appeared to be of fine quality.

Why do some of the cocoas produce this color with iron while others do not? It was suggested by a manufacturer of cocoa through correspondence that it (the greenish-black color) may be due to an alkaloid or to the Dutch Process cocoa having a free alkali present. The cocoa filtrates were first tried with phenolphthalein and found to be acid. Tests with Brom-thymol-blue made by the addition of a small quantity of cocoa filtrate to a neutral solution containing the indicator showed that those cocoas which produced the discoloration had a slightly alkaline pH value (about 7.2), while the others were slightly acid (about 6.6). By the addition of $\frac{N}{10}$ NaOH the pH value of all the filtrates was brought to a slightly alkaline condition and the greenish-black color was produced by all when a solution of ferric chloride was added. The tannins producing this color were, therefore, present in all the samples of cocoa, but are in active form only in the alkaline condition. Subsequent changing of the pH to slightly acid did not affect the production of color.

PREVENTING THE DISCOLORATION

Two methods of preventing the appearance of this discoloration are obvious. The most effective method is the use of cocoa not capable of producing the color. This can be determined, without trying the cocoa in ice cream to see if the discoloration appears, by the addition of a solution of ferric chloride to the cocoa solution as previously described. The other method is the prevention of iron in soluble form from coming in contact with chocolate ice cream. This can be accomplished by the use of well-tinned ice cream cans or by the complete lining of all ice cream cans with exposed iron with the paraffined cardboard can liners that are on the market. The development of the

discoloration can be checked if not entirely stopped when cans with exposed iron are used without can liners by a thorough scrubbing to remove all rust, followed by prompt drying.

SUMMARY

An outbreak of a greenish-black discoloration of chocolate ice cream has been described. It was caused by ferric tannate which was formed by the soluble iron or rusty cans reacting with the tannins in the cocoa. Not all cocoa will produce this discoloration with ferric salts. Three samples of cocoa that gave the discoloration had an alkaline pH value, while five that did not give the color were acid in reaction. The appearance of this discoloration in chocolate ice cream can be prevented by the use of well-tinned or paper lined cans or by the use of cocoa that is not capable of producing it.

NORMAL GROWTH OF THE JERSEY COW

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The normal birth weight of Jersey males and females and the normal growth of the heifers until two years of age has been determined at this station, by Eckles (1, 2). It is well known by dairymen, however, that growth continues for several years. As dairy cattle are bred to calve at approximately two years, the lactation (3) following seriously interferes with normal growth after that age. Still lactation is a normal function of the dairy cow and it is of considerable value to determine the normal growth with age of the lactating dairy cow.

For the past twenty years the American Jersey Cattle Club has required that the weights of all cows completing a Register of Merit record be reported. The object of this paper is to report the results of a study of this data based on the weights of 15680 animals at various ages throughout the entire productive life of the dairy cow. These weights should be typical of the registered cows of the Jersey breed as they include both the American and Island strains.

The average weights for the various ages as shown in table 1 were computed from the individual records with the aid of a correlation table (table 2). It should be pointed out in this connection that the ages represent the time the animals started on test, while the weights were sent to the club at the completion of the record. It would appear that a correction of one year should be made. However, cows on test generally do not gain in weight during the lactation period and therefore the weights at the beginning and close of the test do not vary materially. The weights of many of the cows were estimated but as there is no apparent reason for bias, it is thought that the large number of records reported overcomes this difficulty to a large extent.

From table 2 it will be seen that there were a few cows tested under eighteen months of age at the start of the test. These 26 animals weighed an average of 710 pounds. There were also 1001 yearlings (18 to 24 months) weighing an average of 767 pounds. The largest number of animals come in the class from

TABLE 1

Data on the growth of Jersey cattle

AGE	NUMBER OF ANIMALS INCLUDED	AVERAGE WEIGHT
years		*pounds*
1.5	26	710
1.5–2	1001	767
2–2.5	3155	808
2.5–3	1449	836
3–3.5	1523	872
3.5–4	1122	888
4–4.5	1171	916
4.5–5	916	930
5–6	1692	938
6–7	1235	945
7–8	965	952
8–9	621	957
9–10	364	962
10–11	208	957
11–12	108	968
12–13	64	956
13–14	32	961
14–15	14	1036
15–16	9	975
16–17	4	963

2 to 2.5 years with the number of animals tested gradually decreasing as they become older. The oldest animal tested was eighteen years old while a second one reached the advanced age of over seventeen years.

It will be seen from the figure that the Jersey cow reaches the mature weight of approximately 960 pounds at about eight years of age. It might be noted that Eckles (2) gives the mature weight of the American type Jersey as 902 pounds, a weight considerably below that shown in the figure. This discrepancy does not appear to be due to experimental error as inferred from

TABLE 2

Correlation table of age and weight of Jersey cattle

WEIGHT CLASSES	AGE CLASSES IN YEARS																			TOTAL
	Under 1.5	1.5–2	2–2.5	2.5–3	3–3.5	3.5–4	4–4.5	4.5–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	
lbs.																					
400–450								1													1
450–500		2																			2
500–550	1	6	8	2																	17
550–600		14	9	4	1	1															29
600–650	4	94	124	23	14	4	4	1		2	1										271
650–700	6	107	205	64	30	13	1	1	5	3	3		1								439
700–750	9	205	485	176	91	53	30	15	31	13	11	4	6	2			1				1,132
750–800	3	215	583	192	169	94	69	45	69	45	39	25	5	6	1	2	1				1,563
800–850	2	188	837	377	345	224	204	142	199	146	102	64	31	22	13	2		1	3	1	2,903
850–900	1	90	410	258	280	242	209	151	267	183	112	75	44	19	13	5	4				2,363
900–950		54	333	222	328	244	272	212	422	274	217	143	78	58	29	22	7	3	1	2	2,921
950–1,000		19	89	72	123	117	166	128	246	201	169	88	72	29	12	18	8	2			1,559
1,000–1,050		6	56	48	99	91	141	136	269	231	185	142	76	41	22	12	9	1	4		1,569
1,050–1,100			10	4	25	19	42	44	95	66	61	34	20	16	5	1		3	1		446
1,100–1,150		1	3	5	15	12	26	28	59	45	48	28	23	10	6		2	2			313
1,150–1,200			2		1	4	6	4	16	14	6	11	5	4	2	2				1	78
1,200–1,250			1	1	2	3	1	7	9	7	9	5	2	1	5			2			55
1,250–1,300						1			4	1											6
1,300–1,350									1	3	1	2									7
1,350–1,400											1		1								2
1,400–1,450											1										
1,450–1,500				1						1											2
1,500–1,550								2													2
Total.....	26	1,001	3,155	1,449	1,523	1,122	1,171	917	1,692	1,235	965	621	364	208	108	64	32	14	9	4	15,680

the smoothness of the curve and from the probable error which is only about 3 pounds at eight years.

The distribution of the animals by weight classes at different ages is also clearly shown in table 2 and needs little explanation. The mode of the class under 1.5 years is at the weight class of

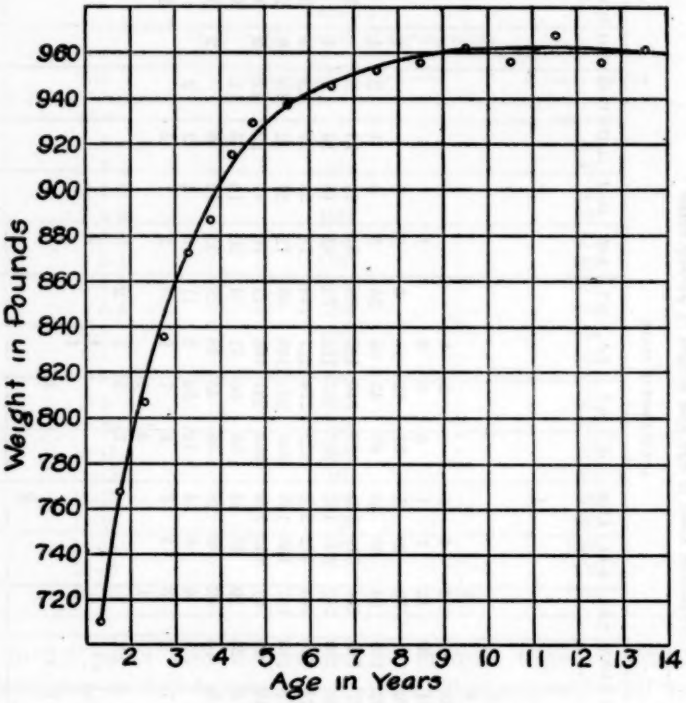

FIG. 1. AGE-WEIGHT CURVE OF THE JERSEY COW

700 to 750 pounds, that of the next class 750 to 800 pounds, while the mode of the two year olds comes in the 800 to 850 pound class. The mature animals are fairly evenly distributed between the 900 to 1050 pound classes.

A theoretical matter might be mentioned in connection with the growth curve.[1] The curve can be represented by an exponential equation of the form

$$X = A\ (1\text{-}e^{-kt})$$

Where X is the weight of the animal at any age t, and A is the mature weight which is seen from the graph to be about 960 pounds. It may be assumed that growth is due to a certain limiting substance produced at the time of conception which is gradually utilized. As soon as this limiting substance or growth impulse is completely utilized, growth ceases.

The weight of the animal may be taken as a measure of the amount of this growth substance used up, and the difference between the mature weight, 960 pounds, and the weight at any age t, a measure of the amount of substance or growth impulse left unused. This equation indicates that the percentage at which this unused substance is used up is the same from year to year. Thus the difference between 960 and the weight at different ages is as follows:

AVERAGE AGE	WEIGHT	DIFFERENCE	PER CENT OF DIFFERENCE
years	*pounds*	*pounds*	
2.5	817	143	
3.5	879	81	56.6
4.5	922	38	46.9
5.5	938	22	57.8
6.5	945	15	68.1
7.5	952	8	53.3
8.5	957	3	37.5

In other words, the percentage decline of the growth limiting substance or growth impulse is approximately constant.

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[1] A theoretical discussion is given in the Journal of General Physiology, Vol. v, No. 4, p. 445–449.

FACTORS INFLUENCING PERCENTAGE OF FAT IN MILK

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The explanation of the variation observed in the fat content of milk from individual cows or herds from one period to another has engaged the attention of investigators for many years. The consensus of opinion is that the fat content depends upon the breed, the individual within the breed, the degree of fatness at time of parturition, and the stage of lactation; and that neither feed nor management can be so varied as to change more than temporarily the percentage of fat.

Since it was established by our work[1] at Brownsville, Texas, that the percentage of fat is lowered by the feeding of prickly pear and that the greater the quantity of pear fed the greater the reduction in fat content, we have from time to time conducted other experiments at the Beltsville station with a view to explaining the results obtained in the feeding of pear, also to find out the influence of other feeds and of certain methods of management.

The outstanding characteristics of prickly pear so far as the analysis is concerned are the high water and mineral contents. It was thought likely that one or both of these constituents were responsible for the lowering of the fat content. Accordingly experiments were conducted[2] in which cows consumed varying quantities of water, with the result that the percentage of fat was found to be unaffected.

The mineral matter of prickly pear differs from that of other green materials mainly in having a large content of calcium and

[1] Hoard's Dairyman, 1916

[2] Jour. Agri. Research, April 24, 1916.

magnesium and a relatively low content of phosphorus. These constituents were investigated separately in a series of experiments which are reported in this paper.

THE EFFECT OF CALCIUM

To find out the influence of calcium, four cows were fed the regular ration consisting of grain, hay, and silage in comparison with the same ration with 1 pound of steamed bone meal added. Two of the cows received the bone meal for twenty days, the check ration for twenty days, then the bone meal for another twenty days. The other two cows received the check ration for twenty days, then the bone-meal ration, and finally the check ration again. The results are seen in table 1.

TABLE 1

Average fat content of milk in experiment with bone-meal ration

	cow 17	cow 21	cow 23	cow 100
	per cent	*per cent*	*per cent*	*per cent*
Bone-meal ration	4.90	5.075		
Check ration	5.025	4.925	4.10	4.40
Bone-meal ration	5.175	5.025	4.325	4.55
Check ration			4.60	4.45
Difference attributed to bone-meal	+0.012	+0.125	−0.025	+0.125

Three of the four cows showed an increase in per cent of fat when bone meal was fed, but the increase was so slight as to be within the range of experimental error. The conclusion that bone meal does not influence the per cent of fat is apparently justified.

Since bone meal contains phosphorus as well as calcium, and the pear has a low phosphorus content, it was thought best to get additional data in which calcium was fed in the form of a carbonate. In the nutrition investigations at this station three cows have been so fed as to admit of four comparisons between a ration containing limestone and one without limestone. In two cases the milk tested higher when limestone was fed and in two cases it tested lower. In view of these facts it was thought that a special experiment on the subject was unnecessary.

THE EFFECT OF LIBERAL MINERAL AND WATER

The next step was to try a combination in which both the water and minerals were lower in one ration than in the other. Two cows were fed a ration low in mineral, consisting of corn silage, cottonseed hulls, and a grain mixture composed of equal parts of corn meal, wheat bran, and cottonseed meal, with 1 per cent salt added. These cows were given only 75 per cent of the quantity of water which they would normally drink. Two other cows at the same time were fed a similar ration with one pound of bone meal added per cow per day, and were allowed all the water they would drink twice daily. At the end of twenty days the rations were reversed. See table 2.

TABLE 2

Average fat content of milk, in experiment with ration low in both minerals and water

	cow 14	cow 64	cow 51	cow 61
	per cent	*per cent*	*per cent*	*per cent*
Normal water, high mineral	4.513	3.614		
Low water, low mineral	5.040	3.655	3.459	5.166
Normal water, high mineral	4.620	3.80	3.574	5.034
Low water, low mineral			3.460	5.090
Increase attributed to low water and low mineral	0.474	−0.052	−0.114	−0.094

In two cases the low water and low mineral apparently increased the per cent of fat and in two cases there was a decrease. The differences are slight except in one instance.

When cows ate prickly pear the total water intake was much in excess of the quantity normally consumed with any usual ration, so another experiment was conducted in which the cows were induced to take a supernormal quantity of water along with 1 pound of bone meal per cow per day, in comparison with the same cows receiving the normal quantity of water and no bone meal. Turnips were fed during one period in such quantities as it was thought would increase the normal water intake 10 to 20 per cent. Table 3 shows the results.

While the data in the two foregoing experiments are too meager to admit of definite conclusions, it appears that high water consumption coupled with high mineral content in the ration does not influence the per cent of fat in milk.

THE EFFECT OF MAGNESIUM

The next experiment with the mineral matter was to try the effect of adding some compound of magnesium to the ration, since as stated above the pear was high in this element. Magnesium carbonate was fed at the rate of 0.3 pound per cow per

TABLE 3

Average fat content of milk, in experiment comparing normal water and low mineral with supernormal water and high mineral in the ration

	cow 33	cow 49	cow 67
	per cent	*per cent*	*per cent*
Normal water, low mineral	4.99	3.91	
Supernormal water, high mineral	4.72	4.17	4.07
Normal water, low mineral	5.15	4.37	4.11
Increase attributed to low water and mineral	0.35	−0.03	0.04

TABLE 4

Average fat content of milk, in experiment with feeding magnesium carbonate

	cow 460	cow 462
	per cent	*per cent*
Check ration	5.33	5.76
Magnesium carbonate	5.18	5.92
Check ration	5.28	6.23
Change attributed to magnesium carbonate	−0.125	−0.075

day in alternate ten-day periods, in each of which eight days were considered experimental. Each individual milking was tested for fat. The ration of grain, hay and silage remained the same throughout.

Cow 462 on check ration in the first eight-day period produced milk with an average fat content of 5.68 per cent; with magnesium carbonate added the milk tested 6.14 per cent; in the second check-ration period the test was 5.76 per cent. In this case the

magnesium gave a higher testing milk, which is contrary to what would be expected.

This cow was continued on the experiment along with cow 460, and the further results by eight-day periods are shown in table 4.

It cannot be stated from this experiment that the magnesium carbonate affected the percentage of fat, as the differences observed are within the range of experimental error.

The results of feeding another compound of magnesium, epsom salt, at the rate of ½ to ¾ pound per cow per day to four cows showed a slight decrease for two cows and a small increase for two cows, as shown in table 5.

TABLE 5

Average fat content of milk, when epsom salt was fed

	cow 6	cow 7	cow 244	cow 249
	per cent	*per cent*	*per cent*	*per cent*
Epsom salt, ½ lb.	3.99	4.68		
Check ration	4.12	4.96	4.35	3.79
Epsom salt, ¾ lb.	4.09	4.90	4.76	3.89
Check ration			4.69	3.89
Change attributed to epsom salt	−0.08	−0.17	+0.24	+0.05

It is realized that there are dozens if not hundreds of combinations in which the mineral matter might occur in the plant, every one of which might exert a different physiological effect upon the animal body. If the lowering of the fat content observed when prickly pear is fed is due to a particular mineral compound the difficulty in finding it will be appreciated in view of the fact that the different mineral combinations in the pear are unknown. For these reasons it has seemed best not to pursue the matter further.

EFFECT OF HIGH-PROTEIN FEEDING

It has been reported that high-protein feeding increases the percentage of fat in milk. To test the accuracy of this statement four cows, two Jersey and two Holstein, were fed large quantities of high-protein feeds, in comparison with a grain

ration composed of hominy feed 100 pounds, ground oats 100 pounds, wheat bran 100 pounds, linseed oil meal 50 pounds, and cottonseed meal 50 pounds, which ration is here designated as "ordinary grain." The feeding was in periods of ten days. During certain periods three-fourths of the usual allowance of the ordinary grain ration was replaced by a high-protein feed. The first two days following the change in ration were discarded in the calculations, this length of time being allowed for the full effect of the change to become manifest. The figures given in table 6 therefore are averages for eight-day periods, calculated from weights and tests taken of each milking. Cow 227 received 10 pounds grain; 439, 9 pounds; 243, 15 pounds; and 466, 12 pounds. The high-protein feed varied from 6.8 to 11.2 pounds per cow daily.

TABLE 6

Average fat content of milk, in experiment with high-protein feeding

	COW 227	COW 439	COW 243	COW 446	ALL COWS
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Ordinary grain	3.32	5.59	3.08	6.14	4.38
Three-fourths cottonseed meal	3.69	6.12	3.38	6.64	4.83
Ordinary grain	3.37	5.70	3.07	5.91	4.37
Three-fourths of linseed oil meal	3.50	6.10	3.51	6.22	4.67
Ordinary grain	3.51	5.46	3.02	5.30	4.16
Three-fourths of gluten feed	3.37	5.70	3.13	5.40	4.17
Ordinary grain	3.56	5.88	3.19	5.33	4.24
Three-fourths of linseed oil meal	3.43	5.86	3.24	4.99	4.16
Three-fourths of linseed oil meal	3.52	5.73	3.22	4.88	4.13
Three-fourths of linseed oil meal	3.58	5.72	3.32	4.90	4.20
Three-fourths of linseed oil meal	3.91	5.96	3.24	4.95	4.30

It will be observed by comparing high-protein periods with an average of the ordinary-grain periods immediate before and after, that in every instance an increase followed the use of the cottonseed meal; and the same is true of the first period in which linseed oil meal was fed. These results confirm those obtained in a previous experiment by R. R. Graves and L. S. Riford at this station, in which two cows were fed 4 to 6 pounds of the oil meals for short periods. Gluten feed had no uniform effect one way or the other, and this is also the case with the last four periods of

linseed oil-meal feeding. Apparently the effect of these feeds on the test is not permanent and it is possible that at the time gluten feed was offered the previous effects had worn off and it was time for the test to drop.

Since the high-protein feeds affecting the test in this experiment are rich in oil as well as protein, the question arose as to whether the increase in percentage of fat was due to the protein or to the oil. Accordingly another experiment was conducted in which linseed oil was compared with linseed oil meal. Six cows were used. Three were fed the ordinary grain ration for ten days, then the same with 0.7 to 1.0 pound linseed oil per cow

TABLE 7

Average fat content of milk, when linseed oil and linseed oil meal were fed in comparison with ordinary grain ration

	COW 434	COW 447	COW 460	ALL COWS
	per cent	*per cent*	*per cent*	*per cent*
Ordinary grain	5.90	6.21	4.62	5.38
Ordinary grain plus linseed oil	6.05	6.31	5.21	5.73
Ordinary grain	5.51	5.53	4.57	5.10
	COW 426	COW 439	COW 468	ALL COWS
Ordinary grain	6.20	5.53	4.89	5.57
Three-fourths of linseed oil meal	6.24	6.26	5.06	5.75
Ordinary grain	5.88	5.37	4.67	5.32

per day for ten days; and this was followed by another 10-day period the same as the first. The other three cows were fed the same, except during the second period when three-fourths of their grain was replaced by linseed oil meal. The first two days of each period was discarded in the calculations, so the figures given in table 7 are averages for eight days. Cows 434, 447, 460, 426, 439, and 468 received the following quantities of grain respectively; 12, 9, 13.5, 14, 10, and 12.6 pounds. Cows 434, 447, and 460 during the second period consumed respectively 0.8, 0.6, and 0.95 pounds of linseed oil daily.

In every case both the meal and oil brought about an increase in the test. Apparently the principal, if not the only, factor increasing the percentage of fat is the oil.

Since gluten feed is low in oil and linseed oil meal is high in oil the effect of these two feeds was compared to get further information on the effect of oil on the test. Six cows divided into groups were run for six ten-day periods. Cows 82, 237, 468, 93, 236, and 254 received respectively 8, 9, 8, 8, 9, and 8 pounds of grain per day. During the second period one-fourth of the grain of one group consisted of gluten feed, and one-fourth of the grain of the other group consisted of linseed oil meal. For the fourth and sixth periods the gluten feed and linseed oil meal made up three-fourths of the entire grain fed. Table 8 shows the results.

TABLE 8

Average fat content of milk, in experiment comparing gluten feed with linseed oil meal

	COW 82	COW 237	COW 468	ALL COWS
	per cent	per cent	per cent	per cent
Ordinary grain	3.95	3.60	4.71	4.06
One-fourth gluten feed	4.11	3.66	5.09	4.23
Ordinary grain	4.10	4.01	4.99	4.35
Three-fourths gluten feed	4.07	3.95	5 01	4.31
Ordinary grain	4.08	4.11	5.31	4.45
Three-fourths gluten feed	4.11	4.07	5.35	4.46
	COW 93	COW 236	COW 254	ALL COWS
Ordinary grain	4.89	3.65	3.51	3.94
One-fourth linseed oil meal	4.96	4.08	3.54	4.15
Ordinary grain	5.15	4.20	3.92	4.41
Three-fourths linseed oil meal	5.65	4.75	4.02	4.80
Ordinary grain	5.25	4.78	3.90	4.72
Three-fourths linseed oil meal	5.44	5.13	4.06	4.99

This experiment shows that the small quantities of either gluten feed or linseed oil meal did not affect the test. The larger quantities of gluten feed did not increase the percentage of fat in the milk, but the linseed oil meal did, though not to so great an extent as in some of the preceding experiments. Possibly this decreased effect is due to the smaller quantities of linseed oil meal fed to these cows.

In order to see how permanent the increase in test was, five cows were fed on a large quantity of linseed oil meal for 40 days,

this being preceded and followed by periods or ordinary feeding. Cows 82, 220, 407, 462, and 468 received respectively 11, 13, 15, 11, and 10 pounds of grain per day. For forty days three-quarters of these quantities were linseed oil meal. In table 9 are shown the results of this experiment.

The average for all the cows shows that after ten days of high linseed oil meal feeding the percentage of fat returns to normal, though the reaction to such feeding is not at all uniform with the different individuals.

TABLE 9

Average fat content of milk, when cows were fed linseed oil meal in large quantity for a long period

	COW 82	COW 220	COW 407	COW 462	COW 468	ALL COWS
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Ordinary grain	4.21	3.80	5.96	6.38	5.77	5.08
Three-quarters linseed oil meal	4.41	4.09	6.13	6.88	5.71	5.30
Three-quarters linseed oil meal	4.11	3.74	6.09	6.66	5.40	5.03
Three-quarters linseed oil meal	3.93	3.85	5.97	6.84	6.08	5.07
Three-quarters linseed oil meal	4.20	3.80	6.20	6.51	5.61	5.06
Ordinary grain	4.08	3.89	6.22	6.76	5.32	5.03
Ordinary grain	4.08	3.75	6.38	6.87	5.54	5.10

EFFECT OF EXERCISE

In the experiments at this station to determine the effect of exercise upon production it was found that cows when they took exercise by walking three miles a day yielded milk containing a slightly higher percentage of fat than when they remained at rest. The details are given in tables 10, 11, and 12.

The investigation was followed up further by making tests of individual milkings of several cows when at rest and when exercised.

In order to solve the question conclusively a more extended test with six cows was made in which each individual milking was analyzed for fat.

Of the 11 cows in the above tables all showed an increase in test when changed from rest to exercise and a decrease when changed from exercise to rest, except in two instances out of

22 possible comparisons. In every case when the average test on exercise was compared with the average on rest, the exercise gave the richer milk. Also the mixed milk showed that exercise increased the test.

TABLE 10

Average fat content of milk from cows when exercising and when at rest, the tests being made of composite samples of milk for two days out of each 10-day period

	FIRST EXPERIMENT							
	Period	Cow 87	Cow 409	Cow 416	Cow 245	Cow 401	Cow 435	All cows
	days	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Rest.....	50	3.38	6.03	5.25	4.17	6.22	5.36	4.76
Exercise..	50	3.64	6.22	5.84	4.30	5.62	5.33	4.92
	SECOND EXPERIMENT							
	Period	Cow 82	Cow 411	Cow 466	Cow 254	Cow 441	Cow 83	All cows
Rest.....	40	3.86	4.67	4.91	3.33	5.25	4.58	4.42
Exercise..	40	3.86	4.78	5.64	3.47	5.18	4.65	4.55

TABLE 11

Average fat content of milk from cows when exercising and when at rest, the tests being made from selected individual milkings

	First group			
	PERIOD	COW 409	COW 416	BOTH COWS
	days	*per cent*	*per cent*	*per cent*
Rest.....	2	5.92	5.21	5.59
Exercise.....	12	6.29	5.58	5.95
Rest.....	8	6.07	5.18	5.69
	Second group			
	PERIOD	COW 245	COW 401	COW 435	ALL COWS
	days	*per cent*	*per cent*	*per cent*	*per cent*
Exercise.....	2	4.55	5.63	5.48	5.19
Rest.....	12	4.29	5.27	5.29	4.90
Exercise.....	4	4.24	5.55	5.38	5.07

EFFECT OF HOT WEATHER

As a rule the composite milk supply from a large number of cows contains a smaller quantity of butterfat in summer than in

winter. There are three possible factors having to do with lowering the test in summer-weather, feed, and recent freshening of cows. The herd maintained at the Dairy Division Experiment Station is one of the few which receives the same feed in summer as in winter and in which the cows freshen at all times of the year. For these reasons it offers exceptional opportunities for studying the effect of hot weather on the percentage of fat.

Ever since the dairy herd was established at this station accurate tests have been made regularly every month of each cow's milk. A two-day composite prepared by taking an aliquot

TABLE 12

Average fat content of milk from cows when exercising and when at rest, the tests being made from all milkings for six to ten days, each milking tested separately

	FIRST GROUP				
	Period	Cow 82	Cow 460	Cow 462	All cows
	days	*per cent*	*per cent*	*per cent*	*per cent*
Rest	6	4.54	4.88	6.10	5.25
Exercise	6	5.20	4.99	6.26	5.52
Exercise	10	5.26	4.74	5.78	5.28
Rest	10	4.73	4.70	5.35	4.97
	SECOND GROUP				
	Period	Cow 220	Cow 401	Cow 461	All cows
Exercise	6	4.59	4.94	6.03	5.07
Rest	6	4.30	5.05	5.83	4.95
Rest	10	4.24	4.93	5.42	4.80
Exercise	10	4.59	5.48	6.02	5.27

portion of each milking is used for testing. To date there are 166 animals with at least one test in January and one in July. These two months were selected as representing the two extremes of temperature. Altogether 830 tests have been made in these two months. Some 426 calvings are represented, 179 of which occurred between the January and July tests, and 247 between July and January tests. A greater number received their first test in January than in July. It is evident, therefore, that in general the July tests were made later in the period of lactation and thus could not account for any lowering of the fat content

in summer. Since such lowering was not due to the feed, nor to the stage of lactation, it could only be due, apparently, to the hot weather of summer. Table 13 gives a compilation of these tests.

In preparing this table the tests for January and July were listed separately for each cow and an average test for each of the two months was obtained. From the averages thus secured the figures given in the table were prepared. They represent, therefore, averages in which the data from each cow receive equal weight regardless of whether the tests are for only two months or several.

TABLE 13

Effect of season on per cent of fat

BREED	NUMBER OF ANIMALS	NUMBER OF CALVINGS		NUMBER OF TESTS		AVERAGE OF TESTS		DIFFERENCE
		January to July	July to January	January	July	January	July	
						per cent	*per cent*	
Jersey	49	39	45	69	93	5.96	5.39	0.57
Holstein	41	54	48	106	126	3.66	3.62	0.04
Guernsey	16	25	24	42	46	5.75	5.03	0.72
Grade Jersey	11	12	42	47	44	5.03	4.94	0.09
Grade Holstein	15	19	15	33	40	4.10	3.98	0.12
Grade Guernsey	22	21	27	46	53	5.20	4.67	0.53
Mixed	12	9	46	49	36	4.37	4.35	0.02
Total	166	179	247	392	438	4.92	4.59	0.33

It is thought that sufficient numbers of animals and tests are included in this compilation to make the results fairly conclusive, though the difference between summer and winter amounts to only .33 per cent. Apparently the test of Holstein cows is not affected by hot weather to so great an extent as that of Jerseys or Guernseys; in fact these data fail to show any appreciable difference between winter and summer tests of Holsteins.

SUMMARY

The feeding of prickly pear lowers the percentage of fat in the milk. The outstanding characteristics of prickly pear analyses are the high water and mineral contents.

The mineral matter is especially high in calcium and magnesium.

Much of the work reported above was done with the idea of finding what particular constituent was responsible for the decrease in percent of fat.

The quantity of water consumed does not affect the test.

Calcium either in the form of bone meal or limestone has no definite influence on the test.

A combination of high water and high mineral feeding as compared with low water and low mineral has no influence on the percentage of fat in the milk.

The carbonate and sulphate of magnesium do not lower the per cent of fat.

The feeding of 7 to 11 pounds per cow per day of cottonseed meal and linseed oil meal caused an increase in the fat content of the milk.

Gluten feed at the rate of 6 to 7½ pounds per day did not affect the test.

Linseed oil has the same effect as linseed oil meal.

Small quantities (2 or 3 pounds) of linseed oil meal do not seem to affect the test.

Apparently the influence of the linseed oil meal feeding on the percentage of fat in milk is temporary.

Since linseed oil exerts the same effect as the meal, and since gluten feed which is low in oil does not affect the test, the conclusion is that the results observed are due to the oil rather than the protein.

Exercise by walking three miles a day increases the test slightly but unmistakably.

Hot weather lowers the test.

The decrease is greater with those breeds yielding naturally a milk high in fat.

THE BACTERIAL CONTENT OF COW FECES*

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In estimating the importance of the different factors which have to do with the contamination of market milk, fecal contamination has sometimes been underestimated. In the past it has been assumed that 5,000,000 bacteria per gram is a fair average for the cow feces which contaminates milk. For fresh feces this average might stand. But it is the feces which has dried on the cows body at near blood heat which generally contaminates milk. When the bacterial content of this type of feces is determined it is found to contain about a billion bacteria per gram. It is easily seen that only a slight amount of contaminating material containing a billion bacteria per gram is needed to increase the bacterial content of milk tremendously. One-tenth of one gram per quart of milk might add half a million bacteria per cubic centimeter of milk.

The above facts were brought out pointedly by Dr. M. J. Prucha[1] in results read before the nineteenth annual meeting of the Society of American Bacteriologists.

It is the object of the work reported here to add further data to that already mentioned.

The media used was standard beef extract agar of reaction about pH = 6.8.

Two hundred and fifty representative colonies were taken from the plates of fresh feces and were placed in litmus milk tubes

*Results obtained from Dairy Herds at University of Illinois and Cornell University.

[1] M. J. Prucha, H. M. Weeter, and W. H. Chambers, Germ life in cow feces, Abs. of Bacteriology, vol. ii, no. 1, p. 6 (1918).

TABLE 1

Bacteria per gram in fresh cow feces

FECES SAMPLES	PLATE COUNT, PER GRAM
1	43,000,000
2	1,000,000
3	30,000,000
4	39,00,000
5	634,000,000
6	26,000,000
7	320,000,000
8	500,000
9	160,000
10	2,640,000
11	21,200,000
12	230,000
13	44,000,000
14	37,000,000
15	378,000,000
16	510,000,000
17	14,000,000
18	20,000,000
19	44,000,000
20	7,000,000
21	14,000,000
22	630,000,000
23	390,000,000
24	53,100,000
25	1,820,000
26	570,000,000
27	5,000,000
28	191,000,000
29	624,000,000
30	1,320,000
31	6,900,000
32	24,600,000
33	27,500,000
34	405,000,000
35	3,300,000
36	78,200,000
37	9,800,000
38	14,000,000
39	11,670,000
40	17,500,000
41	5,860,000
42	265,000,000
43	26,500,000
44	5,940,000
45	525,000,000
46	30,000,000
47	12,760,000
48	23,000,000
49	6,500,000
50	41,600,000

TABLE 2

Bacteria per gram in cows' feces (dried)

Feces were dried on porous plate covers at 37° C. for forty-eight hours.

FECES SAMPLES	PLATE COUNT, PER GRAM
1	6,600,000,000
2	16,800,000,000
3	4,800,000,000
4	2,310,000,000
5	860,000,000
6	1,120,000,000
7	1,340,000,000
8	1,740,000,000
9	3,350,000,000
10	5,360,000,000
11	1,780,000,000
12	1,430,000,000
13	2,120,000,000
14	956,000,000
15	3,160,000,000
16	1,110,000,000
17	710,000,000
18	1,170,000,000
19	1,460,000,000
20	1,340,000,000
21	1,910,000,000
22	670,000,000
23	1,420,000,000
24	500,000,000
25	1,100,000,000
26	5,730,000,000
27	2,040,000,000
28	810,000,000
29	4,190,000,000
30	1,760,000,000
31	1,302,344,000
32	500,000,000
33	2,420,500,000
34	1,250,200,000
35	3,220,000,000
36	990,000,000
37	520,000,000
38	1,500,200,000
39	7,130,000,000
40	1,010,000,000
41	2,310,200,000
42	1,576,000,000
43	870,000,000
44	610,000,000
45	
46	920,000,000
47	1,809,000,000
48	9,130,000,000
49	3,410,000,000
50	810,000,000

which were incubated thirty days at 20°C. The results were as follows:

	per cent
Weak acid forming micrococcus	21.7
Strong acid and gas formers	8.4
Weak alkali forming rods	10.6
Strong liquefying rods (non-gas-forming)	18.7
Neutral micrococcus	12.4
Bacterium lactic acid	9.2
Aerogenes forms	8.4
Strong alkali forming rods	7.6
Fluoresens liquefaciens forms	2.0

It was found that when synthetic media varying between pH = 6.8 to pH = 7.3 were used and an incubation period of twenty days at 28°F., very much higher counts were obtained than are given in the foregoing table giving the bacterial content of cow's held for forty-eight hours. Due to this fact it is considered that flora results obtained from plates vary with the kind of media used. Due to this fact no flora determinations were made of the dried feces and those given for the fresh feces have little significance beyond showing what kind of organisms grow when standard beef extract agar is used.

CONCLUSION

We must revise our conception of how many bacteria one-tenth of a gram of dried cow's feces may add to market milk.

A SYSTEM OF REARING DAIRY CALVES WITH LIMITED USE OF MILK

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In 1907, experiments were begun here relative to methods of rearing calves under conditions where milk and its products were either unavailable or uneconomical to use. The results of studies made from 1907 to 1909 have been published by Savage and Tailby (1). The work described by these authors included studies of various proprietary calf meals and of dried milk products as substitutes for skim milk. In continuation of the work begun in 1907 the studies here reported describe results obtained with a system of feeding which does not involve the use of milk or its products after the first few weeks of age.

The need of such a system in dairy practice is for the dairyman who sells his product as market milk and has no skim milk for calf rearing; for the use of whole milk is too expensive to be practicable in most herds. The problem is by no means a new one. Both American and foreign literature are full of accounts of studies bearing on it. As a result of these studies many partial or complete substitutes for milk have been proposed and a large number of proprietary preparations are on the market. Some of them are enjoying a considerable use in practice, but there evidently still remains much to be desired from the standpoint of satisfactory growth and of freedom from digestive disturbances.

In an endeavor to overcome these limitations, an investigation of the problem has been in progress by the authors since 1919. It has involved experiments with laboratory animals and certain chemical studies of various feeding stuffs, as well as growth and metabolism studies with calves. The latter work has been confined largely to rations formulated at this station, although a few trials of proprietary calf meals have been made. In an endeavor to avoid as much as possible the digestive troubles frequently

encountered in rearing calves, particularly where a substitute for milk is used, certain studies have been made of the relation of intestinal putrefaction and fermentation to these troubles. A preliminary report on this work has been published (2).

The present article deals only with growth studies with calves, made in 1921 and 1922. It seems desirable to publish this portion of the work apart from the rest because it indicates that substantial progress has been made and describes the results obtained with a system of feeding which, it is believed, is a contribution to animal husbandry practice. The present report must be considered a preliminary one, inasmuch as the work still in progress may modify somewhat the recommendations here tentatively suggested, as well as furnish further information on points not yet clear.

EXPERIMENTAL

In the studies reported in this paper, the milk normally received by the calf was replaced at about four weeks of age by a gruel made from the following combination of materials:

250 pounds corn meal
250 pounds red dog flour
150 pounds ground oat groats
150 pounds linseed oil meal
100 pounds ground malted barley
100 pounds soluble blood flour
10 pounds precipitated calcium carbonate
10 pounds precipitated bone meal
10 pounds salt

The above formula, which may be referred to as a calf meal, was found to have the following analysis: water, 9.3 per cent; ash, 5.1 per cent; protein, 24.0 per cent; fiber, 3.5 per cent; N. F. E., 53.7 per cent; and fat, 4.4 per cent. The selection and proportion of ingredients is based on previous studies. The formula is especially designed to be as suitable as possible for the calf during the time when little other feed, such as hay and grain, is consumed. All of the ingredients are highly digestible and have been selected to make the mixture as low as possible in fiber. Each ingredient is finely ground, both because of pre-

sumably easier digestibility and because fineness of division is essential to avoid too rapid settling when the mixture is made into a gruel.

The blood flour furnishes a highly digestible animal protein to supplement the less efficient vegetable protein of the other ingredients. Blood flour has long been considered a valuable ingredient in calf meals both because of its nutrient value and because of a favorable effect in counteracting digestion troubles. The product used by us was entirely soluble in water and was obtained from the United Chemical and Organic Products Company, Chicago, Ill.

Linseed oil meal is another favorite ingredient of calf meals, not only because of its nutrient value but also because of its favorable physical effect. It also aids materially in keeping the meal in suspension in water due to its emulsifying properties.

Malted barley has a special value due to its diastatic action. That its addition results in a certain amount of saccharification of the higher carbohydrates of the other ingredients has been shown by our chemical studies.

It is obvious that a cereal grain mixture is deficient in lime as compared to milk. In earlier studies calcium carbonate alone was used. The combination of carbonate and phosphate was substituted at the suggestion of Dr. E. B. Forbes and we believe it has proved more satisfactory than the carbonate alone. The special sources of carbonate and phosphate used were chosen on the basis of purity, fineness of division and wholesomeness.

One can only speculate as to the suitability of the meal as regards vitamine content, since little is known as to the vitamine requirements of calves. The meal has resulted in normal growth in rats from four weeks of age to maturity. On the basis of the ingredients one would expect it to contain adequate B, to be rather deficient in A, and to be very deficient in C. However, it must be remembered that the calf probably stores some A during the period of whole milk feeding and that both A and C are supplied by roughage of the right character as soon as the calf begins to eat it.

The calves received hay and a dry grain mixture as soon as they would eat those feeds, following in this respect the procedure used with calves reared on milk. The dry grain ration was made up as follows:

30 pounds hominy
30 pounds ground oats
30 pounds wheat bran
10 pounds oil meal

The hay used was good quality clover or alfalfa.

The quality of the hay is especially important where a calf meal is used, because the more palatable it is the sooner the calves commence to eat it in quantity. This in turn develops the digestive tract, enabling it better to handle the substitute for milk. The great superiority of legume hay as regards lime and vitamines is a very important consideration in using it where milk is not fed.

THE CALVES

The animals used in the present trials comprised 7 grade Holsteins, 6 purebred Holsteins, and 2 purebred Shorthorns, all heifers. In all of our trials, with the exception of one of those reported here, the animals were limited, by reason of lack of barn space and other considerations, to those available in the University herd. For comparative purposes animals of the same breed and sex were desired and Holsteins were chosen because they were available in the largest numbers. In the last trial reported here, 2 Shorthorns were used, which represents the beginning of a plan, in so far as animals are available, to see how the calf meal will be handled by other breeds. The grade animals used were purchased from nearby farmers. They were healthy individuals, but not otherwise specially selected. Those calves from the University herd were not specially chosen; rather all available ones were used, except certain individuals deemed too valuable for use on experiment. At no time was any calf removed from the experiment by reason of lack of thrift or difficulty in handling the ration, it being recognized that ability to cause continuous normal growth was the primary measure of the value of the system of feeding.

FEEDING AND MANAGEMENT

The calves were kept in separate stalls and received the same general care accorded to similar animals in the University herd. Each calf was fed whole milk three times a day until the change was made to gruel. This change was usually begun during the fourth or fifth week, the exact time depending on the condition of the calf.

In keeping the calves on whole milk for about four weeks, it was recognized that the period is somewhat longer than holds in practice where skim milk is substituted for whole milk. In previous trials, we have started the substitution of gruel as early as two weeks of age and found it could be done satisfactorily with a fairly long period of change. However, we believe that feeding whole milk to about four weeks of age gives the animal enough better start, enabling a more rapid change to gruel with less digestive upset, to be worth while even though more whole milk is thus required.

About three weeks were allowed for making the change from milk to gruel. For calves over four weeks of age at the beginning of the change a shorter period usually sufficed. With all calves the period of change was governed by the condition of the calf rather than by any set rule. The beginning and duration of the period of change is shown for each calf in connection with figures 1, 2 and 4.

The gruel was made by mixing 1 pound of the calf meal with 5 pounds of water at about 100°F. It was fed three times a day. In changing from milk to gruel the first addition of the latter was that which would correspond to a daily ration of about ¼ pound of the calf meal. Beginning with this initial addendum, the gruel was gradually increased and the milk decreased until the change was completed. The milk and gruel were fed together. Assuming that a calf was receiving 12 pounds of whole milk before the period of change, the following illustrates a possible feeding schedule during the actual period:

DAY	WHOLE MILK	GRUEL
	pounds	pounds
1	9.0	1.5
5	7.5	3.0
8	6.0	4.5
11	4.5	6.0
14	3.0	7.5
17	1.5	9.0
20	0	9.0

It must be emphasized, however, that no set schedule was maintained with any calf. The length of the period of change, the times of increasing the addendum of meal and the actual amount of milk and gruel fed were all governed by the condition of the calf. If a given mixture of milk and gruel produced digestive disturbances, as shown by liquid or pasty and foul-smelling stools, no further change was made until these conditions disappeared. If they persisted for three or four days the food was usually cut down in amount, temporarily, or perhaps omitted entirely for a feeding. Sometimes in extreme cases, the proportion of milk to gruel was increased temporarily. This procedure was followed in recognition of the principles that it is not what the calf eats, but what it assimilates that is of benefit, and that it is better to underfeed the animal to the extent of a temporary retardation of growth rather than to cause digestion troubles which, if continuing for any considerable period, are difficult to overcome and result in slow growth over a protracted period. These principles apply to the calf reared on milk and they must apply with double force where a food much less suitable to the digestive system of the animal is being used. Detailed mention has been made of the feeding during the period of change because it is believed that the system of feeding according to the condition of the individual animal has been an important factor in the results obtained.

Having completed the change from milk to gruel, the latter was gradually increased with the appetite and condition of the calf. In general, no increase was made for at least a week after discontinuing the milk, thus keeping the gruel below what the calf might actually consume, in order to get it well started on the

ration containing no milk. If the calf is carried through the period of change and for a week or so thereafter with only slight digestive upsets, the time of greatest possible trouble is over. The animal is accustomed to the change in food and is at an age when some hay and dry grain is being eaten and when its digestive system is becoming developed to handle the more bulky and less digestible feeds. For regular and maximum growth, however, the condition of the animal must be constantly watched to avoid overfeeding and digestive upsets, and the feed regulated accordingly. In general, the maximum daily feeding of gruel has been 15 pounds (2½ pounds calf meal) in these studies, usually fed during the fifth and sixth months. Many calves will eat more than this amount during this period, but it is more economical for them to get the rest of their nutriment out of dry grain and hay since they can handle the latter feeds in quantity at this time.

Hay and the dry grain were placed before the calves at three to four weeks of age. In general neither was consumed in any quantity until the seventh or eighth week. The rule followed in feeding hay and grain was to allow the calves all they would clean up. The grain mixture was fed twice daily in such amounts as would be cleaned up within an hour after feeding. The calves were watered twice daily.

With the idea of making up possible vitamine deficiencies a small addendum of carrots was made to the ration in the second trial reported in this paper. Carrots are rich in C and contain some A, the two vitamines most likely to be deficient under our system of feeding as has been pointed out. Bearing in mind that the period of most probable deficiency is during the time when little or no milk is being consumed and before the legume hay is eaten in any quantity, it was decided to begin the carrot feeding with the inauguration of the change from milk to meal. Since it was questionable whether calves four weeks old would handle raw carrots satisfactorily it was decided at the start to cook the carrots and to change to raw after the calf had gone through the transition period from milk to meal. It was recognized that cooking would destroy part of the vitamine C content, but it seemed better to accept such a loss than to add in raw carrots

another possible factor contributing to digestion troubles during the period of change. The carrots were run through a food chopper, covered with boiling water and boiled for five minutes—a procedure designed to furnish the desired cooking with minimum loss of C. With the beginning of the change from milk to meal the cooked material, without any removal of water, was added to the milk—gruel mixture in an amount equivalent to $\frac{1}{10}$ pound of carrots per day. The addendum was gradually increased until at the time the milk was discontinued the calf was receiving $\frac{1}{2}$ pound of cooked carrots daily. At about this time, a change was made to chopped raw carrots, fed with the dry grain mixture. It was our practice not to begin with raw carrots until the calf was at least six weeks of age and eating $\frac{1}{2}$ pound of dry grain a day. The feeding of raw carrots was begun at $\frac{2}{10}$ pound per day and gradually increased to 1 pound per day, which was in general the maximum amount fed. The rate of increase depended on the grain consumption. The maximum addendum was not attempted until the calf was eating at least $1\frac{1}{2}$ pounds of dry grain daily. Some calves, of course, were much slower than others in reaching this figure. All the calves, with 1 exception, ate the carrots readily. No unfavorable results occurred from feeding them as far as could be observed.

THE MEASURE OF GROWTH

The ideal method of measuring the success attained with the system of feeding here described would be to compare the growth and development with that of a check lot reared on skim milk. Such a procedure was followed in an earlier trial, but was later given up because of lack of animals. With the publication by Eckles (3) of data as to the normal growth of dairy cattle, a very useful measure for our work became available. This investigator made a study of the growth from birth of the purebred dairy animals of the Missouri herd, recording the monthly increase in weight and height at withers, and thus was able to construct normal growth curves for the different breeds, based on a large number of individuals. Our results have been compared with these curves. As calves, the animals studied by Eckles were

reared on skim milk together with grain and hay, usually alfalfa, from two weeks of age to six months, and were evidently subject to the same general conditions of management as obtain at the barns here. However, it is probable that our animals had an advantage as regards liberality of feeding, since they were given all the grain they would eat, while those reared at Missouri were evidently limited somewhat in this respect.

We were able to secure a few data from the University herd as to the growth of calves reared on skim milk when receiving all the grain they would clean up. The observations shown in table 1 were made during a period nearly corresponding to the one in which the second trial reported in this paper was carried out and embraced animals which were not included in the calf meal experiment, because of plans for their early disposal or other reasons.

TABLE 1

Average daily gain of purebred Holstein heifer calves reared on skim milk

CALF	WEIGHT AT BIRTH	WEIGHT AT SIX MONTHS	AVERAGE DAILY GAIN
	pounds	pounds	
E–9	95	421	1.81
213	100	411	1.73
221	99	408	1.72
222	96	396	1.66
223	88	390	1.68
225	91	391	1.67
Average.....	95	402	1.71

The average daily gain shown in table 1 is 1.71 pounds in comparison to a figure of 1.44 pounds obtained from Eckles' data. Of course, as a fair mean, the figure of Eckles is more reliable because based on a much larger number of individuals, embracing animals born in every month of the year. Though more comparable as regards method of feeding, the data in table 1 are less useful than Eckles' for measuring the success attained in our trials because, due to lack of periodic weighings, no opportunity is afforded for comparing the regularity of the rate of growth, a measure especially desired with a system of feeding likely to cause

temporary upsets. Thus Eckles' curves have been our principal basis of comparison. We have been careful, however, to point out, as will be noted in the discussion of the results which follows, the limitations involved. As a supplementary measure for comparison, the data in table 1 have been used.

The calves used in the studies here reported were weighed at birth, and weekly during the experimental period. The weighings were made at the same time of day so chosen as to be as long as possible after feeding or watering. To obtain the weight at the close of the six months experimental period, an average was taken of weighings on three successive days.

In the second trial, height at withers was measured at birth and monthly thereafter, taking an average of three measurements. Such measurements are subject to considerable error, but when plotted as was done by Eckles the trend of the curve indicates whether skeletal development is keeping pace with increase in weight.

In addition to increase in weight and height there are certain other measures of condition and development which are important in judging the success of a given ration, though they are difficult of quantitative expression. The experienced observer needs no scales or measuring stick to detect a thrifty animal. The character of the coat, the nature of the excreta, the shape of the belly and the activity of the animal all indicate how the feed is being handled. Careful observations were made from day to day of these less expressible measures of growth. They were used constantly in regulating the feed of the animals.

RESULTS

It is convenient to discuss separately the results obtained in the two trials reported since the experimental conditions were somewhat different. For this discussion the trials will be referred to as series A and B.

Series A

This trial was conducted in the summer and fall of 1921 using the 7 grade Holstein heifer calves previously mentioned.

The growth curves of these calves are shown in figure 1. It is noted that these curves do not start at the same point as the accompanying curve of normal growth. This is due to the fact that, being purchased calves, their birth weights were not known. However, their ages were known and the first point on the curve represents the weight at the age at which they were received at the University barn. The vertical dotted lines setting off the period of change from whole milk to gruel show that the change was usually begun somewhat later than at four weeks of age, as planned. This was due to the fact that most of the animals were three or four weeks old when received and the desirability of

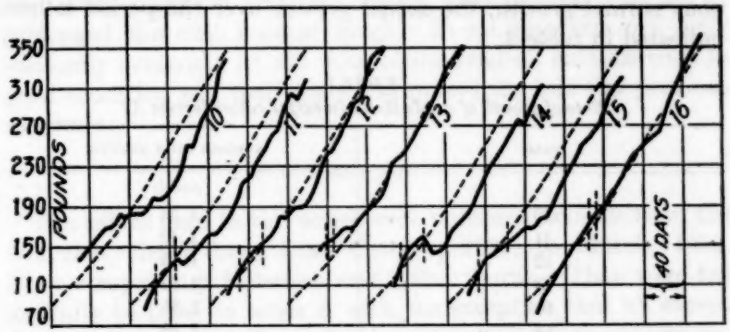

FIG. 1. CURVES OF GROWTH IN WEIGHT OF HOLSTEIN HEIFER CALVES (SERIES A)

The dotted curves represent normal growth according to Eckles' data.

The vertical dotted lines mark off the period during which the change was made from milk to gruel.

continuing the milk feeding until they became accustomed to their new surroundings, necessitated the delay. It is noted that growth was rather irregular, many instances of actual loss of weight being recorded. In several cases, these losses corresponded with periods of extremely hot weather and cannot be charged entirely to the nature of the ration. However, the curves show that most of the animals suffered at least a temporary check in rate of growth as soon as the milk was entirely removed, indicating that the system of feeding was not conducive to the regular normal growth desired. No check occurred with calves 12 and 16. For all of the calves, except calf 16, the period of

change and the subsequent four or five weeks coincided with the hottest months of summer. Thus, the results shown were obtained under the most adverse weather conditions. Further, each calf spent a day at three or four different times during the period following the change in a metabolism cage, which generally adversely affected appetite and disposition. Some metabolism studies were made with calf 16 while it was on milk, and this explains why the period of change was begun later for this calf. Thus the animal got a better start on milk than the others and this may account for the better and more uniform growth.

Though figure 1 shows the extent of success in securing continuous normal growth, the actual growth over the period is best indicated in table 2.

TABLE 2

Rate of growth of grade Holstein heifer calves (series A)

CALF	AVERAGE DAILY GROWTH
	pounds
10	1.34
11	1.40
12	1.55
13	1.40
14	1.31
15	1.40
16	1.67
Average	1.44

The average rate of growth of the animals on which Eckles' normal curve was based is 1.44 pounds per day. The data reported in table 2 show an identical average, a figure, however, that falls considerably short of the 1.71 pounds per day shown in table 1. The averages reported in table 2 do not cover the entire six months period since the rate of growth of the first two or three weeks could not be recorded. Omitting this period of slower growth would tend to make the figure reported larger than the true average for the full six months. The calves reported in table 2 were at a disadvantage with respect to those of Eckles in being grade animals, reared during the most unfavorable

season and subject to the disturbances of the metabolism cage. On the other hand, they may have been fed more liberally. Though fed comparably to those reported in table 1 they were poorer individuals and were at a decided disadvantage as regards the time of year in which they were reared.

No serious digestive disturbances were caused by the gruel feeding. There were occasional instances of liquid or pasty and rather bad-smelling stools, but these difficulties always cleared up in a few days with a proper regulation of the food. The periods of retarded growth corresponded in general with those in which the food was cut down either due to lack of appetite or temporary digestion trouble. Where these periods were at all prolonged the coat became rough. In no case was pot belly markedly evident. At the close of the trial all animals were in good condition and their coats had practically lost any previous roughness.

Series B

The calves used in this series were purebred animals from the University herd, born from October, 1921, to March, 1922. They comprised 6 Holsteins and 2 Shorthorns. They were fed similarly to those in series A with the exception that all except the Shorthorn calf 133, received carrots fed as previously described. Calf 133 received no carrots, but was fed mangels, beginning with the tenth week. The growth curves for the Holstein calves are shown in figure 2. It is noted that all calves exceeded the check curve, 4 of them markedly. No retardation of growth is indicated following the omission of the milk. Over the entire six months the growth is seen to be regular, practically paralleling or exceeding the check curve at every period. It is believed that these results, showing regular normal growth free from digestion troubles even during the period of change and immediately thereafter, constitute the most important feature of the work here reported. A more regular growth than occurred in series A would be expected because of the more favorable weather conditions, better individuals, and absence of experimental disturbances. Nevertheless it is felt that the addition of

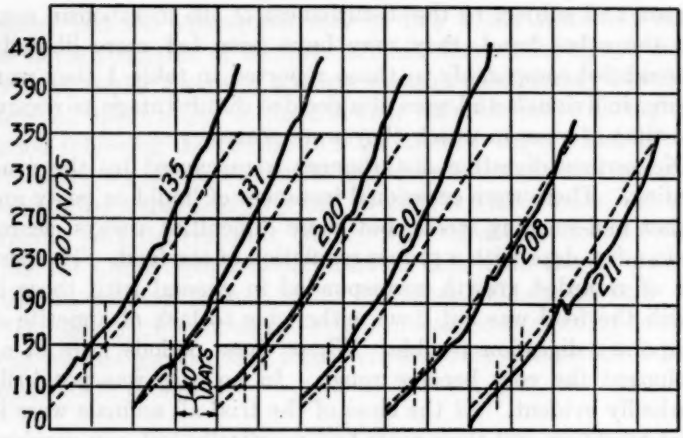

FIG. 2. CURVES OF GROWTH IN WEIGHT OF HOLSTEIN HEIFER CALVES (SERIES B)

The dotted curves represent normal growth according to Eckles' data.
The vertical dotted lines mark off the period during which the change was made from milk to gruel.

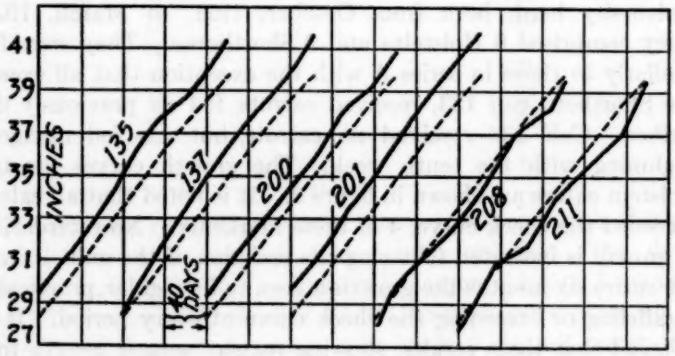

FIG. 3. CURVES OF GROWTH IN HEIGHT AT WITHERS OF HOLSTEIN HEIFER CALVES (SERIES B)

The dotted curves represent normal growth according to Eckles' data.
The abscissas mark off periods of forty days.

carrots to the ration must have also been a factor. A comparison of the results with some obtained the previous winter, where no carrots were fed, indicates that the carrots must have had a favorable effect on growth.

That the growth as shown by increase in weight was accompanied by a corresponding skeletal development is shown in figure 3. The curves for increase in height at withers are seen to equal or exceed the check, even as occurred in the case of the weight measurements.

The extent of the growth obtained is best shown in table 3.

TABLE 3

Rate of growth of purebred Holstein heifer calves (series B)

CALF	WEIGHT AT BIRTH	WEIGHT AT SIX MONTHS	AVERAGE DAILY GAIN
	pounds	*pounds*	*pounds*
135	105	416	1.73
137	90	423	1.85
200	107	408	1.67
201	99	438	1.88
208	88	365	1.54
211	77	350	1.52
Average.....	94	400	1.70

In making an average daily gain of 1.70 pounds per day the group of calves reported in table 3 equaled the average gain made by the six similar animals reported in table 1 which were reared on skim milk in a nearly identical period. Thus, it would appear that under our system of feeding results were secured comparable in both rate and regularity of growth to those obtained with calves reared on skim milk.

As would be indicated from the regularity of the growth, the calves in series B experienced little digestion trouble, being more free from it than those in series A. It is believed that there was little if any more occurrence of abnormal feces and of going-off feed than occurred with the group reared on skim milk.

The results obtained with the Shorthorn calves are shown in figures 4 and 5. Eckles' data as to the increase in height of

Shorthorns begin at thirty days instead of at birth, which explains the starting point of the dotted curve in figure 4. Both the calves are seen to have exceeded the average. It is not worth while to discuss the results with only 2 individuals of a breed except to point out that the results support those obtained with the Holsteins.

In reporting the work described in series A and B, it has been our primary object to show that calves can, by a proper system of feeding, be reared satisfactorily without milk after four to

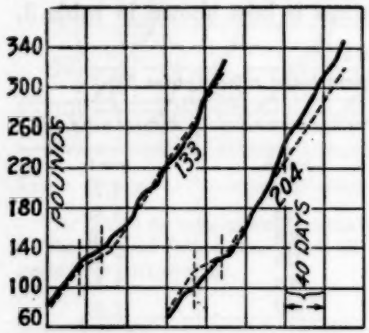

FIG. 4. CURVES OF GROWTH IN WEIGHT OF SHORTHORN HEIFER CALVES (SERIES B)

The dotted curves represent normal growth according to Eckles' data.

The vertical dotted lines mark off the period during which the change was made from milk to gruel.

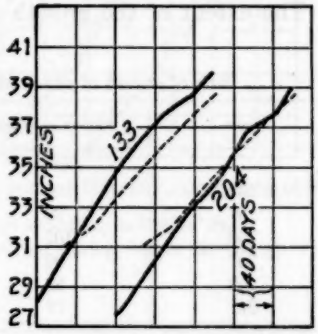

FIG. 5. CURVES OF GROWTH IN HEIGHT AT WITHERS OF SHORTHORN HEIFER CALVES (SERIES B)

The dotted curves represent normal growth according to Eckles' data (curves begin at age thirty days).

eight weeks of age, and that gains comparable to those produced by skim milk are possible. The work leaves many questions, some of great practical interest, unanswered. No mention has been made of the amount of food consumed and the cost thereof. Though we have feed records for the work reported, these records are not as accurate as desired, and it seemed best to postpone the report on feed consumption and cost until there is completed the studies now in progress especially planned to overcome the difficulties of securing accurate data on these points.

That the carrots were in part responsible for the excellent results in series B is probable but not proved. By the use of a check lot not receiving carrots it is hoped to clear up this point in the studies now in progress. Our results showed that the addition of carrots stimulated the consumption of dry grain. The question arises as to whether the effect of the carrots lay solely in causing the calf to eat more food or whether they constituted an otherwise useful constituent of the ration, perhaps furnishing a needed vitamine. It is hoped that the work now in progress will furnish some answer to these questions.

Just what contribution to the success of the results is made by beginning the carrot feeding as early as was done, and whether cooking is necessary at this stage, are points which must be made clear because of the questionable practicability of the procedure. The question further arises as to whether other roots, such as mangels, would be as satisfactory as the carrots.

The system of feeding here described is by no means recommended to replace the use of skim milk. Where the latter is available, it constitutes the more economical and presumably the more satisfactory method. In its absence, the results obtained with the system of feeding described are believed such as to commend it as a useful alternative.

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STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

VII. THE USE OF THE SELF-FEEDER WITH YOUNG DAIRY CALVES

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Appetite, as an indicator of physiological needs, has been minimized by many investigators in the field of human and animal nutrition. From the beginning the whole animal kingdom has been controlled in its feeding problems only by appetite and environmental limitations of the feed supply. Consequently, even though the rôle of appetite be not of great importance under artificial experimental conditions, yet, if the broad facts of the case, the continued existence and multiplication of man and other animals after countless eons of feeding with appetite as their sole guide, be taken into consideration, it must be recognized as of some value.

RÉSUMÉ OF PREVIOUS WORK

The attention that has been given to the study of appetite can hardly be called critical. Evvard (54) has reviewed the literature on the subject and shown that appetite is a fairly reliable indicator of the physiological needs of the pig. A very limited amount of work has been done with cattle, but other material, not obtained with a view to studying the appetite of animals, may be reviewed here as of interest in connection with the work reported on the grinding of grain for calves.

It has been stated by Jordan (56) that the grinding of oats and corn increased their digestibility in the case of horses, though with sheep whole oats were as completely utilized as ground grain.

It has been found by Fain and Jarnagin (55) that, where corn meal and shelled corn were used to supplement skim milk for calves, the daily consumption of shelled corn was greater than that of corn meal, though the rate of gain was greater and the amount of grain consumed per 100 pounds live weight gain less in the case of the shelled corn. Kildee (57) also recommended whole oats in preference to ground oats for calves. Otis (58) found that calves fed shelled corn made larger gains and consumed less skim milk and hay, but slightly more grain per 100 pounds live weight gain, than did those fed corn chop. He also found that skim milk calves, two to three months old, consumed about 10 pounds of water per head daily.

TABLE 56

Animals used

	CALF 411	CALF 413	CALF 414
Breed	Guernsey	Ayrshire	Holstein
Sex	Male	Female	Female
Initial age, days	70	37	30
Initial weight, pounds	146	110	110

In view of the work that has been done with the self-feeder as an adjunct in the management of other types of live stock this work was undertaken with young calves. The main object was to determine the ability of calves to select rations suited to their needs, to see their preferences for the various concentrates and obtain some knowledge of their demands for salt water.

EXPERIMENTAL WORK

Three calves, 2 heifers and a bull were used. All were in good growthy condition and information concerning them is given in table 56.

From the time they were taken from their dams at about three days of age, until the beginning of the experiment, the calves had been fed whole milk. All had become accustomed to consuming small quantities of hay, while the bull, no. 411, was the only one familiar with grain.

The experiment lasted for two periods of thirty days each, and throughout this time the animals were given what milk was thought to be suited to their needs, skim milk being used to replace part of the whole milk as they became older. A supply of alfalfa hay, of medium quality, was kept before the animals at all times. A self-feeder in the pen contained the following feeds in separate compartments:

Shelled corn	Linseed oil meal (O.P.)
Cracked corn	Wheat bran
Whole oats	Corn gluten feed
Ground oats	Salt
Hominy feed	Charcoal

For a few hours each day fresh water was kept in front of the calves.

TABLE 57

Individual milk consumption (arbitrarily allowed)

	PERIOD I			PERIOD II		
	Calf 411	Calf 413	Calf 414	Calf 411	Calf 413	Calf 414
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Whole milk	276	294	294	226	226	226
Skim milk	84	42	42	226	226	226
Total milk	360	336	336	452	452	452

At the beginning of the experiment and at the end of each thirty-day period the animals were weighed on each of three consecutive days. The average of the three consecutive weighings was taken as the live weight of the animals.

A daily record was kept of the amounts of milk, hay and water consumed and records of the other feeds used were obtained for each thirty-day period. Moisture determinations were made on all feeds to allow of the computation of the total water and dry matter consumption.

DISCUSSION OF RESULTS

Milk consumption records were obtained for each animal and in table 57 are given by thirty-day periods. In period I the bull

was given more milk than the heifers, but during period II each animal received 226 pounds of whole milk with an equal quantity of skim milk.

The total consumption for the group, of whole and skim milk, the various concentrates, hay, salt, charcoal and water are collected in table 58.

TABLE 58

Total feed consumption

	PERIOD I	PERIOD II
	pounds	*pounds*
Milk:		
Whole	864.0	678.0
Skim	168.0	678.0
Concentrates:		
Shelled corn	1.3	108.6
Cracked corn	0.0	0.3
Whole oats	58.7	68.4
Ground oats	0.4	0.5
Hominy feed	0.0	0.3
Gluten feed	15.3	1.9
Wheat bran	13.3	17.3
Oil meal (O.P.)	62.7	75.6
Alfalfa hay	32.7	91.9
Salt	1.1	0.3
Charcoal	0.7	1.3
Water	384.0	689.0

The relative consumption of whole and ground grains can be more clearly appreciated when they are considered separately.

From this evidence one fact is very apparent—the calves showed a decided preference for the whole rather than the ground grains. During period I practically no corn was consumed but in period II there were 108.6 pounds of whole corn and only 0.3 of a pound of cracked corn taken. The whole oats was consumed to the extent of 58.7 pounds in the first period and 68.4 pounds in the second period while never more than 0.5 of a pound of ground oats was consumed in thirty days. Hominy

feed was also neglected in favor of the whole corn and oats. The total consumption of whole grain was 237 pounds while that of ground grain was 1.5 pounds.

Oil meal was the most favored of the nitrogenous concentrates, and the consumption of it increased as the experiment progressed. Wheat bran was a poor second while gluten feed appeared to be the least desirable, as only 1.9 pounds of it were consumed during period II as compared with a consumption of 15.3 pounds in period I. This decided decrease in consumption of gluten feed may perhaps be linked up with the increase in consumption of shelled corn, which in turn was probably due to another factor, the skim milk increase in the ration.

As the experiment progressed the daily allowance of skim milk was increased at the expense of the whole milk. This tended to narrow the nutritive ratio of the ration. The calves counteracted this, however, by increasing their consumption of low protein concentrates from 60.4 pounds in period I to 178.1 pounds in period II, or 195 per cent, while the increase in their consumption of high protein concentrates was relatively small, going from 91.3 pounds in period I to 94.8 pounds in period II, or only 4 per cent.

The consumption of alfalfa hay, water and charcoal increased as the experiment progressed, while that of salt decreased.

From this it is apparent that the consumption of grain, hay and water increased very rapidly with the growth of the calves, the average daily requirements of water mounting from 4.27 pounds in period I to 7.66 pounds in period II.

This again demonstrates the rapid increase in dry matter consumption from 290.9 pounds in period I to 463.2 pounds in period II, while the total consumption of water, as drinking water and in the feed, increased from 1311.3 pounds to 1948.2 pounds, or from 14.57 pounds per day in period I to 21.65 pounds per day in period II.

The live weight gains were very creditable, varying from 1.60 pounds to 2.30 pounds and averaging 1.98 pounds per head per day. The calves did not become too fat but remained in good growthy condition—that most desirable for young dairy calves.

TABLE 59

Consumption of whole and ground grains

	PERIOD I	PERIOD II	TOTAL
	pounds	*pounds*	*pounds*
Whole grain:			
Corn	1.3	108.6	
Oats	58.7	68.4	237.0
Ground grain:			
Corn	0.0	0.3	
Oats	0.4	0.5	
Hominy	0.3	0.0	1.5

TABLE 60

Average daily feed per calf

	PERIOD I	PERIOD II
	pounds	*pounds*
Whole milk	9.60	7.53
Skim milk	1.87	7.53
Concentrates	1.69	3.03
Hay	0.36	1.02
Salt	0.012	0.003
Charcoal	0.008	0.013
Water	4.27	7.66

TABLE 61

Consumption of dry matter and water

	CONSTITUENT			
	Dry matter		Water	
	Period I	Period II	Period I	Period II
	pounds	*pounds*	*pounds*	*pounds*
Milk	127.8	153.3	904.2	1,202.7
Concentrates	133.6	230.4	18.1	42.5
Hay	27.7	77.9	5.0	14.0
Condiments	1.8	1.6		
Water			384.0	689.0
Total	290.9	463.2	1,311.3	1,948.2

TABLE 62

Live weight gains

	CALF 411	CALF 413	CALF 414	TOTAL	AVERAGE
	pounds	*pounds*	*pounds*	*pounds*	*pounds*
Live weights:					
Initial	146	110	110	366	122
Middle	209	158	164	530	177
Final	278	219	226	723	241
Live weight gains:					
Period I	63	48	54	165	55
Period II	69	61	62	192	64
Total	132	109	116	357	119
Average daily gains:					
Period I	2.10	1.60	1.80	5.50	1.83
Period II	2.30	2.03	2.07	6.40	2.13
Average	2.20	1.82	1.93	5.95	1.98

TABLE 63

Feed required for 100 pounds live weight gain

	PERIOD I	PERIOD II
	pounds	*pounds*
Whole milk	524	353
Skim milk	102	353
Grain	92	142
Hay	20	48
Water, drinking	233	359
Total dry matter	176	241
Total water	795	1,015

TABLE 64

Actual and expected consumption of nutrients by calves

	PERIOD I		PERIOD II	
	Actual nutrients	Expected nutrients	Actual nutrients	Expected nutrients
Total dry matter, pounds	209.9	267.9	463.2	412.8
Digestible crude protein, pounds	66.4	43.8	94.1	60.9
Total digestible nutrients, pounds	292.8	230.1	425.1	327.9
Nutritive ratio	1:3.4	1:4.3	1:3.5	1:4.4

The feed requirements per 100 pounds of live weight gain are relatively low.

The calves showed distinct preferences for some of the grain preparation, but there is the question, how near did they come to balancing their rations in accordance with the concepts of modern feeding standards?

The consumption of dry matter and digestible nutrients by the calves is seen to be well above expectations but it has already been shown that the heavy feed consumption led to large and economical gains. According to the Modified Wolff-Lehmann Feeding Standard the feed for the calves should on the average have had a nutritive ratio of 1:4.3 in the first period and 1:4.4 in the second. However, the calves seemed to prefer a ration with a much narrower nutritive ratio. For the first and second periods the nutritive ratios of the rations were 1:3.4 and 1:3.5, respectively. In this choice of a narrower nutritive ratio the calves may have been correct. The calves grew rapidly and gained in weight but did not become too fat and this is the desirable method of growing out young dairy animals.

SUMMARY

This work is too limited in scope to allow of the making of definite recommendations but a few points of interest stand out clearly:

1. Young calves prefer whole corn and oats to the ground grains.
2. Hominy feed does not appear to be palatable to calves.
3. Linseed oil meal (O.P.) appears to be more palatable than wheat bran, while corn gluten feed is not in favor with calves.
4. Calves have the ability to vary their consumption of concentrates to comply with their needs. For example, when whole milk is replaced by skim milk the calves increase their relative consumption of low protein concentrate feeds such as corn and oats.
5. The calves used in this work consumed a ration of much narrower nutritive ratio than is generally recommended.

6. The calves maintained the nutritive ratio of their ration fairly constant though it became slightly wider as the calves advanced in age.

7. The consumption of hay increased materially as the calves became older.

8. Salt and charcoal were evidently desired by the calves.

9. Water is important, even for calves fed milk.

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